

Minimising firefighters' exposure to toxic fire effluents

Interim Best Practice Report

An independent report by  with a foreword by FBU General Secretary Matt Wrack

Commissioned by 



FOREWORD

As firefighters, we all know of a colleague or former colleague that has been diagnosed with cancer or another serious illness – and many will have lost their lives. But here in the UK, there is a frightening lack of research into the effects of the firefighting job on the long term health of those on the front line.

That is what led the Fire Brigades Union to commission independent, ground-breaking research, led by Professor Anna Stec from the University of Central Lancashire (UCLan), into the link between firefighters' occupational exposure to toxic fire effluents, and cancer and other diseases.

This report not only provides evidence of the heightened risk faced by firefighters through their work, but also delivers clear and authoritative guidance to fire and rescue services across the UK about the measures they can take to minimise firefighters' exposure to contaminants.

The report details how firefighters face danger from breathing and ingesting contaminants long after a fire has been extinguished – and how these toxic fire effluents can be absorbed by the skin. It demonstrates where current Fire and Rescue health and safety practices are failing, builds on existing good practice and sets out a path to a safer future.

In producing this report, Professor Stec and her team not only summarised available scientific evidence through a comprehensive literature review, but also conducted contaminant testing on-site at a number of fire and rescue service stations in the UK, analysing over 1000 collected samples. The team also surveyed over 10,000 firefighters and analysed the range of decontamination practices implemented by fire and rescue services in the UK and around the world.

We believe that the scientific study and basis for the production of this guidance will also be of value to those with a broader interest in the exposure of firefighters to toxic fire effluents and debris.

We are pleased to note that ahead of UCLan's report release, the House of Commons Environmental Audit Committee recommended that the Health and Safety Executive (HSE) implement its recommendations on improving firefighters' work environments. In response the government confirmed that it would instruct HSE to monitor the research and to ensure fire and rescue services identify risks to firefighters.

The research is jointly funded by UCLan and the Firefighters 100 Lottery. Buying tickets for the lottery remains the best way to support the next stage of this vital work which requires more in-depth testing of firefighters' work environments, and is already underway in a number of fire stations and training centres across the country. Everyone who supports the lottery has helped to support this vital research.



We are extremely proud to have commissioned this ground-breaking project, and we dedicate it to all those in the fire and rescue service whose lives have, and continue to be, effected by cancer and other diseases.

Health and safety is not a luxury, and we must all do what we can to make work safer for firefighters: Remember the dead, fight for the living.

A handwritten signature in black ink that reads "M. Wrack". The signature is written in a cursive style with a large, stylized 'M' and 'W'.

Matt Wrack
FBU general secretary



**Interim
Best Practice Report
Minimising Firefighters' Exposure
to Toxic Fire Effluents**

We dedicate this report to all firefighters who are battling with, or who have lost their battle with, cancer.

BE AWARE, STAY SAFE

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ACKNOWLEDGMENT

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SUMMARY

A growing body of evidence suggests that firefighters have an increased risk of developing cancer and other diseases compared to the general population. This increased risk may be linked to firefighters' occupational exposure to toxic fire effluents (LeMasters et al., 2006).

In summer 2019, **Environmental Audit Committee**, House of Commons, recommended that:

“the Health and Safety Executive monitors the progress of the Fire Brigades Union research and provides assistance in implementing recommendations which seek to improve the work environments of UK firefighters.

This should include measures to minimise contamination from clothing and equipment and reduce the overall exposure of firefighters, their families and the public”.

(UK Parliament House of Commons Environmental Audit Committee, 2019)

As the best practice report it aims to help protect firefighters' health by highlighting some of the risks and common sources and suggesting preventative measures for minimising exposure to contaminants and best practice for the decontamination of FRS personnel and firefighting equipment after exposure to toxic fire effluent. It provides background information, statistics, resources and actions vital for improving firefighters' health and well-being, keeping them safe and preventing the contamination which otherwise will lead to serious health conditions resulting in either life-changing problems and/or premature death,

The authors and contributors acknowledge that practice from one FRS to the next can vary significantly, and that this practice is based largely on what works best for a specific Service taking into account the number of personnel and local risks, knowledge and experience. This interim report is therefore written with the expectation that it will build on and improve existing practices. It is intended that this is adopted by the fire sector as the best practice. The scientific study and basis for the production of this guidance, will also be of value to anybody with a broader interest in exposure of firefighters to fire effluents and debris.

ABOUT THE AUTHOR



Professor Anna Stec is a world leader in the area between fire safety and public health. She brings a diverse portfolio of research interests including quantification of toxic hazards in fires, understanding the factors that affect fire gas toxicity, and the relationship between the physiological effects of the concentration and dose of different toxicants.

Prof Stec was the Scientific Coordinator for the “Toxicological and Environmental Aspects” workpackage of the EU Flaretex COST Action. She was one of only two UK academics appointed to Dame Judith Hackitt’s Review of Building Regulations and Fire Safety, where she highlighted the need to introduce regulation on smoke toxicity. She was selected as an Expert Witness to the Grenfell Tower Inquiry. She was appointed to Scientific Advisory Group to oversee investigation of soil contamination and adverse health effects following the Grenfell Tower fire. She also presented crucial evidence to the UK Parliament’s Environmental Audit Committee for their report on “Toxic Chemicals in Everyday Life”.

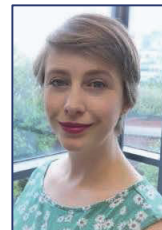
Prof Stec is a member of several scientific and conference programme committees and journal editorial boards. She is an external examiner and peer reviewer for the Government of Alberta (Canada) and Danish Agency for Science and Higher Education. She is a Fellow of both the Institution of Fire Engineers (FIFireE) and the Royal Society of Chemistry (FRSC), chartered scientist of the Science Council and an expert of the British Burn Association. She is also UK’s designated principal expert on the ISO Fire Threat to People and the Environment subcommittee (ISO TC92/SC3).

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METHODS

Literature Review

A number of existing international guidance documents were also reviewed along with published academic literature in order to identify worldwide best practices for minimising contamination of firefighters and their PPE.

UK FRS Decontamination Policies

In 2019, UK FRSs were asked to provide details of their decontamination policies for consideration in this best practice document. 80% of all UK FRSs returned information or procedures regarding:

- PPE decontamination, maintenance, storage, cleaning, repair and replacement;
- Guidance on clothing worn under PPE;
- Details of any cleaning facilities at local stations;
- Details of any training documents that are issued to firefighters.

UK National Firefighter Survey

Data was additionally collected via an online national survey, in which 64 questions assessed the everyday practices and personal experiences of firefighters with regards to fire effluent exposure and decontamination. In 2019/20, the survey was run for 4 months by the University of Central Lancashire (UCLan) assisted by the Fire Brigades Union (FBU) The survey was supported by a number of FRSs in respect of allowing staff paid time to complete the questions. The survey amassed a total of 10, 659 responses (10, 653 of which were included in further analyses). Results of the survey are referenced throughout this best practice document.

UK FRS Contaminant Testing

A key part of this stage involved UCLan's team visiting FRSs to measure levels of identified contaminants harmful to health at various workplaces. These measurements were used to inform targeted best practice recommendations within this best practice document.

LIST OF ABBREVIATIONS

APF	Assigned Protection Factor
BaP	Benzo(a)pyrene
FBU	Fire Brigades Union
FDS	Flexi Duty System
FFP	Filtering Face Piece
FRS	Fire and Rescue Service
HEPA	High Efficiency Particulate Air filter
HFRs	Halogenated Flame Retardants
HBr	Hydrogen Bromide
HCl	Hydrogen Chloride
HSE	Health and Safety Executive (UK)
MDI	Methylene Diphenyl Diisocyanate
NIOSH	National Institute for Occupational Safety and Health
OIC	Officer in Charge
OSB	Oriented Strand Board
PAH	Polycyclic Aromatic Hydrocarbons
PBDEs	Polybrominated Diphenyl Ethers
PCBs	Polychlorinated Biphenyls
PCDD	Polychlorinated Dibenzo-p-dioxins
PCDF	Polychlorinated Dibenzofurans
PM_{2.5}	Particulate Matter with a diameter <2.5µm
PM₁₀	Particulate Matter with a diameter <10µm
PPE	Personal Protective Equipment
RDS	Retained Duty System
SCBA	Self-contained Breathing Apparatus
SVOC	Semi-volatile Organic Compound
SVF	Synthetic Vitreous Fibre
TCPP	Tris(1-chloro-2-propyl)phosphate
TDI	Toluene Diisocyanate
UCLan	University of Central Lancashire
VOC	Volatile Organic Compound
WHO	World Health Organisation

KEY RECOMMENDATIONS

Key recommendations are divided into two subgroups:

For Fire Personnel:

- Respiratory protective equipment (e.g. SCBA) should be worn at all times whilst firefighting. This should also include during salvage and turning over activities and other activities undertaken by FRS personnel (and/or others) after firefighting has been completed, but whilst the building contents are still 'gassing off'. Respiratory protective equipment should be one of the last items of PPE removed during de-robing (after decontamination).
- PPE that is suspected of being contaminated should be transported back to the station or workplace in an air-tight container to prevent cross-contamination.
- Avoid eating, drinking or smoking with unwashed hands whilst wearing, or after de-robing PPE that may be contaminated.
- After attending a fire incident, all personnel should change into a set of clean, dry clothes as soon as possible, ideally before re-entering the appliance (or FDS vehicle).
- PPE should be clean and should be thoroughly decontaminated after every incident to avoid a build-up of toxic contaminants. PPE should be inspected for wear and damage on a regular basis, and replaced as necessary.
- It is important to protect areas of exposed skin and airways when cleaning soiled PPE/equipment. This requires appropriate respiratory protection (e.g. face masks or face coverings) and gloves.
- "Shower within an hour" when returning to the station from an incident, or following a live fire training exercise.
- Regular health screening and recording attendance at fire incidents over the course of a firefighter's career is strongly advised and will be key to the longer-term monitoring and management of health.

For Fire and Rescue Services:

- Every Fire and Rescue Service (FRS) must have fully risk-assessed decontamination procedures (en-route to, during and after fire incidents), and ensure all relevant staff are trained in implementing these procedures.
- All FRS personnel should receive regular and up-to-date training on the harmful health effects of exposure to toxic fire effluents, and how these exposures can be reduced, minimised or eliminated.
- All FRSs should have policies in place for the routine care, maintenance, inspection and professional cleaning of PPE.
- Establishing and strictly maintaining “designated zones” within the fire station must be a priority for preventing cross-contamination. PPE should never be worn in areas of the station designated a clean zone (e.g. kitchens, living quarters etc.) and should be stored away from personal items.
- To reduce secondary exposures, appliance cabs and equipment from emergency response vehicles should be cleaned and decontaminated on a regular basis, especially after incidents where exposure to any combustion products occurred.



INTRODUCTION

Chemical and building regulations are designed to ensure that exposure to materials within residential, commercial and industrial buildings are safe. However, there are currently no requirements to consider how the safety of those materials might change in the event of a fire – i.e. **there are no requirements to measure and quantify the toxic fire effluents produced by burning materials.** There are no restrictions on the use of products capable of emitting lethal quantities of toxic effluents during a fire. Compared with natural materials (wood, wool, cotton, leather, etc.), widely used synthetic polymers (derived from oil) burn more quickly, have faster flame spread, generate more heat and produce not only higher numbers of hazardous gases and particulates, but also much higher concentrations of toxic chemicals. Firefighters are therefore at an increased risk of exposure to toxic fire effluents and subsequently at an increased risk of suffering adverse health outcomes.

Firefighters' exposure to toxic fire effluents will depend on:

- Fire Scenario (fire conditions)
- Fuel (materials involved in the fire)
- Specific toxicants released during and post fire
- Contamination from fire debris/residues
- Type, frequency and duration of fires attended
- The tactics employed at the incident
- The extinguishing medium used
- Use of Personal Protection Equipment
- Hygiene facilities and practices
- Time between contamination and the use of hygiene facilities and practices



Contaminants, Toxicity and Exposure Pathways

*Harm to health depends on the **toxicity** of the contaminant, but also on the **exposure pathways** via which an individual is exposed to the contaminant, and the **dose** (amount) of the contaminant an individual is exposed to (Duffus & Worth, 2006).*

Fires produce a cocktail of toxic, irritant and carcinogenic chemicals – the composition of which varies depending on the specific materials burning and the fire conditions. They can be released in the form of particulates which will include aerosols, dusts, fibres, smoke and fumes or gases and vapours.

Some of these fire effluents (e.g. carbon monoxide, hydrogen cyanide and acid gases) have *immediate* adverse effects on health after only a single or short exposure (e.g. asphyxiation). This is known as **acute toxicity**.

However, most other fire effluents (e.g. volatile organic compounds, or polycyclic aromatic hydrocarbons) have much *longer-term* adverse effects on health, causing conditions which are more complex and can develop more slowly e.g. cancer, cardiovascular (related to the circulatory system which comprises the heart and blood vessels) and neurological (nervous system) diseases. This is known as **chronic toxicity**. Repeated exposure to even very small amounts of chronic toxicants over time increases the likelihood of developing long-term health conditions.

Acute and chronic toxicants can be then further classified according to the specific types of adverse effects they have on health. These classifications are referenced throughout this guide, and include:



- **Carcinogens**; substances which cause cancer (e.g. benzene, PAHs etc.).
- **Teratogens**; substances that can harm the foetus if exposure occurs during pregnancy (e.g. lead compounds, ethylene oxide, formamide etc.).



- **Sensitisers**; substances which result in an allergic type hypersensitivity reaction (e.g. of skin or lungs) (e.g. chromium, formaldehyde, isocyanates etc.).
- **Irritants**; substances which react in contact with moisture on/within the body and cause an inflammatory response (e.g. hydrogen chloride, hydrogen bromide, sulphur dioxide, nitrogen oxides etc.).

It has been proven that combinations of different chemicals which are not particularly harmful individually can give rise to entirely new hazardous effects. Moreover, the effects of chronic toxicants may be cumulative, and can remain latent for a long time before any symptoms arise or are even measurable. (Heys et al., 2016)

Firefighters may be exposed to toxic contaminants via multiple **exposure pathways**:



Inhalation. Many gases, vapours, mists, dusts and fibres released during fires can be inhaled through the lungs. The amount of contaminant inhaled by a person is directly linked to the volume of air inspired and expired, which increases with physical exertion. Normal breathing frequency at rest is 12-20 breaths per minute (approx. 7-14 litres of air). However, under extreme stress, firefighters with normal lung capacity can metabolise up to 100 litres of air per minute (Swedish Civil Contingencies Agency, 2015).



Dermal Absorption occurs when a toxicant comes into contact with an individual's skin. There are many situations in which firefighters' skin comes into contact with harmful substances e.g. through direct contact with soot (touching the skin with contaminated hands or with gloves that have been in contact with fire debris) or when an area of skin is exposed in a smoky environment. Absorption of toxicants via the skin will vary depending on exposure time, the quantity and type of substance, location and the surface area of the skin. The physical demands of firefighting (wearing breathing apparatus, performing rescues, post fire activities etc.) and the high temperatures in which firefighters operate increases their blood flow, sweating rates and body temperature. Together with the body's reduced water content, this leads to increased dermal absorption of fire effluents.



Ingestion (through the gastro-intestinal tract) occurs when a toxicant is swallowed. Exposure to contaminants via ingestion may occur when food or drink is contaminated with fire effluents, e.g. if eating/drinking with soiled hands. In addition, when fire gases or particulates have entered the upper respiratory tract via inhalation, they may be carried via mucous and saliva into the digestive system and absorbed into the body.



*

EXAMPLES OF TOXIC FIRE EFFLUENTS

The below examples illustrate some of the most common types of toxic contaminants that firefighters might be exposed to at fire incidents. Table 1 (page 21) further expands these examples, summarising the key sources of each group of common fire contaminants as well as the overall type of toxicity and/or health effects they have.

Volatile and Semi-Volatile Organic Compounds (VOCs/SVOCs)

Complex mixtures of VOCs/SVOCs are generated as incomplete combustion products during fires, and many of them are known to be significantly damaging to human health and the environment. Important examples of these compounds are benzene, styrene, and phenol, formed in the majority of fires. Benzene is of particular toxicological significance as it is a precursor of carcinogenic polycyclic aromatic hydrocarbons (PAHs) as well as being a known carcinogen in its own right. They are environmentally persistent and able to bioaccumulate in fatty tissues (Anna A. Stec, 2017).

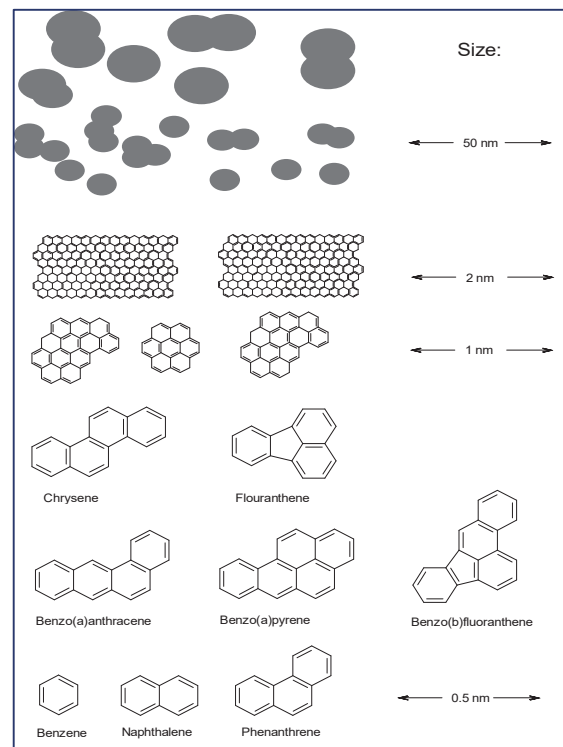


Figure 1: Soot formation which is made from VOCs/SVOCs precursors of PAHs

* *Chimney Sweep's carcinoma* was the first reported form of occupational cancer i.e. cancer caused by occupational exposures (in this case, exposure to particles of soot), and was first identified by Percivall Pott in 1775.

Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons are aromatic hydrocarbons with two or more fused benzene rings (see above, Figure 1). These are large molecules composed of several aromatic rings fused together (example is shown in Figure 2). Many PAHs are carcinogens and environmental pollutants. The molecular size of PAHs strongly influences their distribution between gas and condensed phases and is directly relevant to their toxicity. Smaller PAHs (fewer than four fused rings, e.g. naphthalene, phenanthrene) mainly exist in the gas phase. The tendency to adsorb onto organic carbon (e.g. soot particles) increases with increasing molecular size, so the larger compounds (more than four fused rings, such as benzo(a)pyrene) occur in the atmosphere mainly as particulates (Blomqvist et al., 2010).

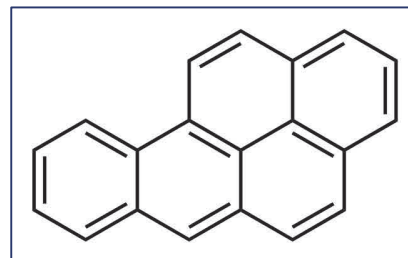


Figure 2: Chemical structure of Benzo(a)pyrene (BaP)

Historically, benzo(a)pyrene (BaP) has been identified as the most toxic PAH species and is used as a reference toxicant for other PAHs. However, recent studies have identified 7,12-dimethylbenzo(a)anthracene as being twice as toxic as BaP. Both compounds have been identified in deposits collected from firefighters' working environments (Stec et al., 2018).

Particulates

Particulate matter is made up of a mixture of small solid and/or liquid particles. The toxic effect of these particles depends on their size and how deeply they are able to penetrate the respiratory tract. Figure 3 shows the deposition zones for different particle sizes within the respiratory tract. Larger particles tend to be trapped in the upper respiratory tract where they are eventually returned to the oesophagus to be excreted then through the gut (where they are ingested like food).

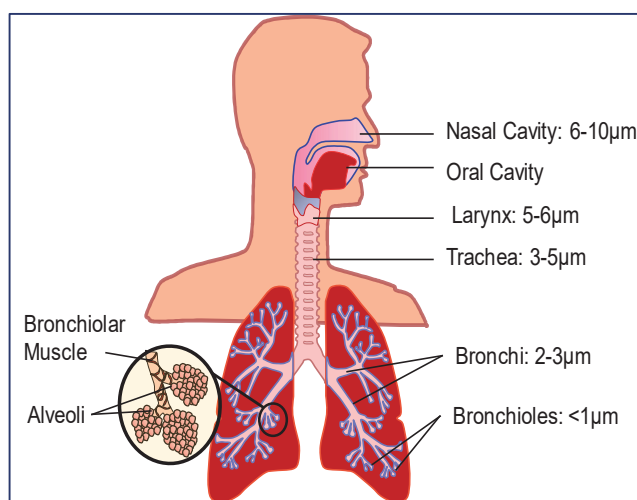


Figure 3: Deposition zone for particulate matter in the respiratory tract

The smallest particles (less than 1 μm), penetrate into the lung interstitium (between the alveolar surface and the blood capillaries), where they can be particularly dangerous, causing interstitial and luminal oedema. They can also cross the air-blood barrier and enter the blood stream, triggering dangerous immune responses from white blood cells, including polymer fume fever and increased platelet stickiness. This can lead to heart attacks or oedema (flooding of the lung) and ultimately death.

Many toxicants, including molecular PAHs, absorb onto carbonaceous particles and therefore travel deep into the lung, rather than being trapped further up (Blomqvist et al., 2010; Anna A. Stec, 2017).

WHO studies estimate a staggering 0.5% increase in daily mortality per 10 $\mu\text{g m}^{-3}$ of PM_{10} (particulates with a size of 10 μm or smaller).
(World Health Organization, 2005)

Isocyanates

These are potent respiratory sensitisers which can trigger asthma, and even death after a single exposure. Isocyanates are commonly identified in fire effluents from burning nitrogen-containing fuel. Due to their versatility and wide range of applications, isocyanate containing products can be found in significant quantities throughout the built environment. They are widely used in the manufacture of polyurethanes, used as foams in soft furniture and building insulation, as solids for resilient elastomers, and liquids and sprays for paints. The two main products in the isocyanate market, with an approximate market share of 90%, are both di-isocyanates: toluene-di-isocyanate (TDI) and diphenylmethane-di-isocyanate (MDI).

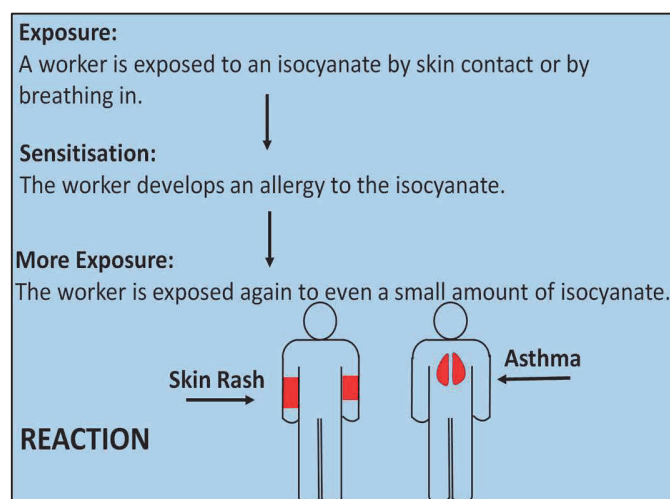


Figure 4: Sensitization caused by an exposure to isocyanates

Halogenated Dioxins

Polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDFs) are toxic, chemically and thermally stable, and have a tendency for being easily adsorbed on the surface of particulate matter. PCDD/Fs formation is favoured at lower temperatures typical of fires. Numerous studies on animals have confirmed that some dioxins are carcinogenic and/or mutagenic (A A Stec et al., 2013).

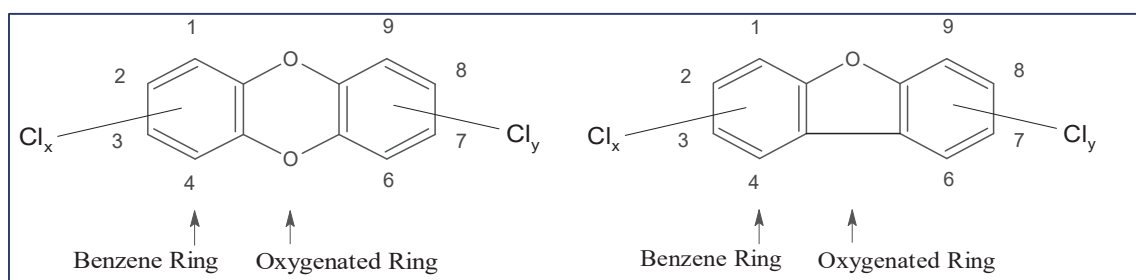


Figure 5: Structure of (a) polychlorinated dioxins and (b) polychlorinated dibenzofurans PCDF

PCDD/Fs have been identified in abundance around the collapsed World Trade Center in 2001 (Litten et al., 2003) and, more recently (together with other persistent organic fire pollutants), they were identified in soil following the Grenfell Tower fire (Stec et al., 2019).

Halogenated Fire Retardants (HFRs)

Halogenated flame retardants (containing chlorine or bromine) have proven effective in suppressing ignition. HFRs act by releasing hydrogen bromide (HBr) or hydrogen chloride (HCl) which interferes with gas phase free radical reactions, reducing heat release, but typically producing more hydrogen cyanide and carbon monoxide, smoke and other products of incomplete combustion. The dense smoke obscures escape routes and contaminates property, while the resultant halogen acids are highly corrosive irritants. Many flame retardants are toxic before they decompose.

They are typically added at loadings of 10 to 20% - thus a flame retarded UK sofa could contain over 1 kg of toxic tris(1-chloro-2-propyl)phosphate (TCPP) (Mckenna et al., 2018).



Figure 6: Polyurethane foam containing halogenated flame retardants (TCPP)

Synthetic Vitreous Fibres (SVFs)

Synthetic vitreous fibres are commonly used in building products, such as insulation materials (polyurethane, phenolic or polyisocyanurate foams). Recently, concerns have been raised over the health hazards posed by these fibres. Studies on the aftermath of the World Trade Center showed that synthetic vitreous fibres were one of the most significant health damaging contaminants (via dermal irritation and inhalation) after the fire (Lippmann, 2014; Lippmann et al., 2015).

Airborne SVFs, like other particulate matter, are released in fires and can be suspended in air (as dust or ash), which can then be inhaled and deposited in the lungs (ATSDR (The Agency for Toxic Substances and Disease Registry), 2018).

Minimum critical fibre lengths for asbestosis (interstitial fibrosis), mesothelioma and lung cancer have been found to be $\sim 2\ \mu\text{m}$, $\sim 5\ \mu\text{m}$ and $\sim 15\ \mu\text{m}$, respectively. For asbestosis and lung cancer, fibres with diameters $>0.15\ \mu\text{m}$ appear to be most significant (as thinner fibres can be more readily cleared via the lymphatic system) whilst for mesothelioma (and other lesions of the mesothelium), fibre diameters $<0.1\ \mu\text{m}$ seem to be the most pathogenic (Lippmann, 2014)

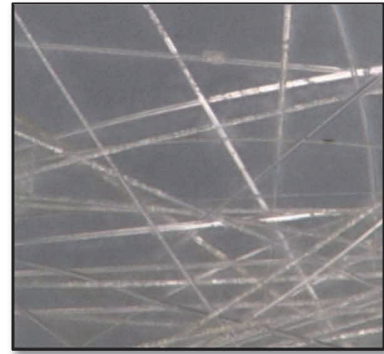


Figure 7: An example of SVFs found in building insulation products

Group of chronic fire effluents	Possible sources	Name of specific fire effluent	Carcinogenic	Teratogenic	Sensitising	Reproductive	Neurological	Pulmonary	Respiratory	Haematological	
SVOC/VOCs	Released in almost every fire. Emitted by an extensive range of household and industrial products, including (but not limited to) cleaning products, aerosols, fuels, furnishings, and building materials. May be given off over the lifetime of a material, or at high concentrations when a material burns.	Benzene	+	+		+	+	+	+	+	
		Styrene		+		+			+	+	
		Toluene		+				+			
		Phenol		+				+			+
		Acetaldehyde		+				+			+
Isocyanates	Used in the production of polyurethane, polyisocyanurate foams, fillers and coatings or any other nitrogen-containing fuels. May be given off over the lifetime of a material, or at high concentrations when a material smoulders or burns.	Methyl Isocyanate (MIC)		+		+		+			
		2,4-and 2,6-toluenediisocyanate (TDI)	+	+		+		+			
PAHs	PAHs are a family of hydrocarbon compounds which are produced in virtually all uncontrolled fires, since they are made up primarily from carbon. They are persistent and generally non-volatile at room temperature, though adhere to airborne particulates so may be found in debris or in the air.	Benzo[a]pyrene	+	+		+					
		Benzo[a]anthracene	+	+				+			
		Benzo[b]fluoranthene	+	+							
		Chrysene	+	+			+				
		Fluoranthene			+				+		+
PCCD/PCDFs	Persistent, bioaccumulative and toxic released from halogen (chlorine) containing fuels, such as PVC windows, cables, fire retardants.	2,3,7,8 TCDD	+	+		+		+			
		2,3,7,8 TCDF		+							
PCBs	PCBs are found in electrical equipment, and are commonly released at electrical and waste fires, though may be found in effluent from any building fire from materials containing chlorine (see above).	3,3',4,4',5,5'-hexaCB	+	+		+			+		
		2,3,4,4',5-pentaCB	+	+		+	+	+	+		
PFOA/PFOS	PFOA and PFOS are released from furniture, carpets, electronics, electrical wire casing, firefighting foams.	Perfluorooctanoic acid (PFOA)	+	+		+			+		
		Perfluorooctane sulphononic acid (PFOS)	+	+		+			+		
Flame retardants	Gas phase halogenated organophosphorus flame retardants are used in almost all combustible insulation foams (phenolic, polyurethane, polyisocyanurate), upholstered furniture, mattresses etc.	Tris(1-chloro-2-propyl) phosphate (TCPP)	+						+		
		Tris(2-chloroethyl) phosphate (TCEP)	+						+		

Table 1: Common fire effluents, the sources from which they originate and their longer-term effects on firefighters' health.

FIREFIGHTER OCCUPATIONAL HEALTH RISKS: CANCERS AND DISEASES

Cancers

Over 4% of UK serving firefighters who responded to the survey have already been diagnosed with cancer.

(FBU & UCLan National Firefighter survey)

The International Agency for Research on Cancer (IARC) has classified many of the substances that firefighters are exposed to as human carcinogens or probable human carcinogens (IARC, 2010). Chronic toxicants are predominantly associated with delayed or chronic effects and disorders such as genotoxicity, mutagenicity, carcinogenicity, neurological disorders etc., which generally occur due to repeated exposure to toxins. Common fire effluents, the sources from which they originate and their longer-term effects on firefighters' health are listed in Table 1. Unlike other countries such as America, Canada and Australia the occupation of firefighting within Great Britain has not been recognised or recorded as an occupation 'at risk' of cancer.



Figure 8: % of Respondents to the FBU & UCLan National Firefighter survey who indicated they had received a cancer diagnosis, and the length of time they had served in the Fire Service before their first diagnosis. Results show the responses from 4.1% of all serving firefighters who completed the survey.

However, the occurrence of disease and cancer among firefighters is higher than expected. There are a number of studies worldwide indicating elevated incidences of certain diseases and cancers within firefighters (Jalilian et al., 2019; LeMasters et al., 2006; Navarro et al., 2019; Petersen et al., 2018; Pukkala et al., 2014). According to a study conducted by NIOSH, USA firefighters have a 9 percent higher risk of being diagnosed with cancer and a 14 percent higher risk of dying from cancer than the general U.S. population (Daniels, 2017). There also appears to be a significantly elevated number of premature deaths amongst firefighters worldwide. Data from the FBU & UCLan National Firefighter survey shows that over 4% of serving firefighters who responded have already been diagnosed with cancer (survey excluded retired firefighters). Their specific cancers are listed in Figure 9.

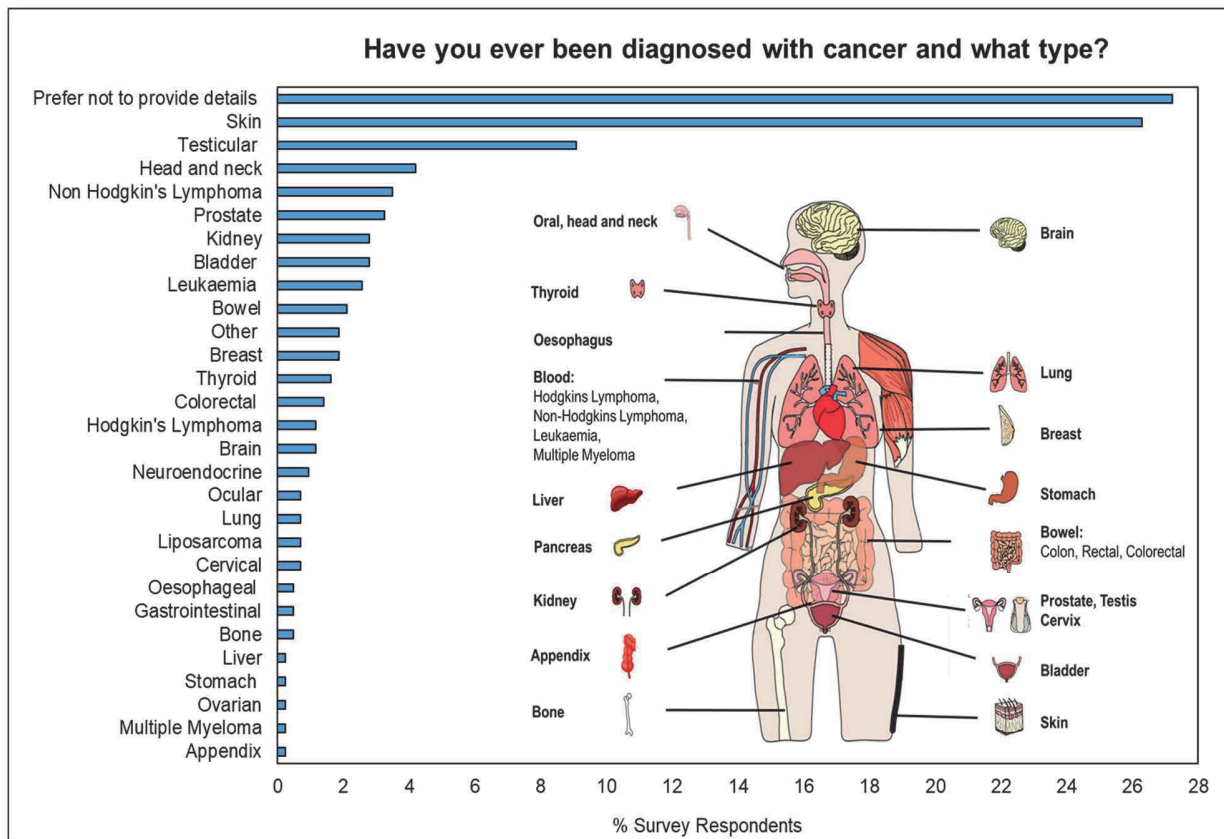


Figure 9: % of respondents to the FBU & UCLan National Firefighter Survey who indicated that they had received a cancer diagnosis, excluding those who received their diagnosis before joining the Fire Service (4% of all respondents to this question including those which omitted to indicate when they received their first diagnosis (1%). A further 0.2% indicated they had been diagnosed with cancer prior to joining the Fire Service).

A number of studies also present a likely latent period for firefighters between the first exposure and diagnosis of cancer, Table 2. It is found that brain cancer or leukaemia typically develop within 5 years, solid tumours such as: testicular, bladder, colorectal, kidney, skin melanoma, multiple myeloma, non-Hodgkin's lymphoma, prostate or lung cancers develop in about 10 to 15 years, oesophageal cancer up to 25 years and mesothelioma 30 to 40 years (Daniels et al., 2014, 2015; T. Guidotti, 2014; T. I. Guidotti, 2007; LeMasters et al., 2006). However, this data should be reviewed carefully as firefighters have different types of roles and activities, and will be exposed to a complex and changing mix of exposures (different fuels and combustion products, multiple exposure routes etc.) – all of which may impact this latent period and lead to earlier occurrences.

Primary Site Cancers	Exposure to Smoke (Minimum Service)
Brain cancer Leukaemia	5 years
Breast cancer Testicular cancer	10 years
Bladder cancer Colorectal cancer Kidney cancer Lung cancer Multiple Myeloma Non-Hodkin's Lymphoma Prostate cancer Skin cancer Ureter cancer	15 years
Oesophageal cancer	25 years
Mesothelioma	30-40 years

Table 2: Possible latent period for firefighters between the first exposure and diagnosis of cancer (Daniels et al., 2014, 2015; Guidotti, 2014; Guidotti, 2007; LeMasters et al., 2006).

Diseases

Over 86% of UK serving firefighters who responded indicated they do not smoke.
(FBU & UCLan National Firefighter survey)

Firefighters are expected to have less premature deaths and diseases, since as a group they are generally healthier than the general population. This is widely known as the “Healthy Worker Effect”, and considers the physical demands of the job, the necessity to pass fitness tests and the requirement to undergo medical checking on a regular basis (Chowdhury et al., 2017).

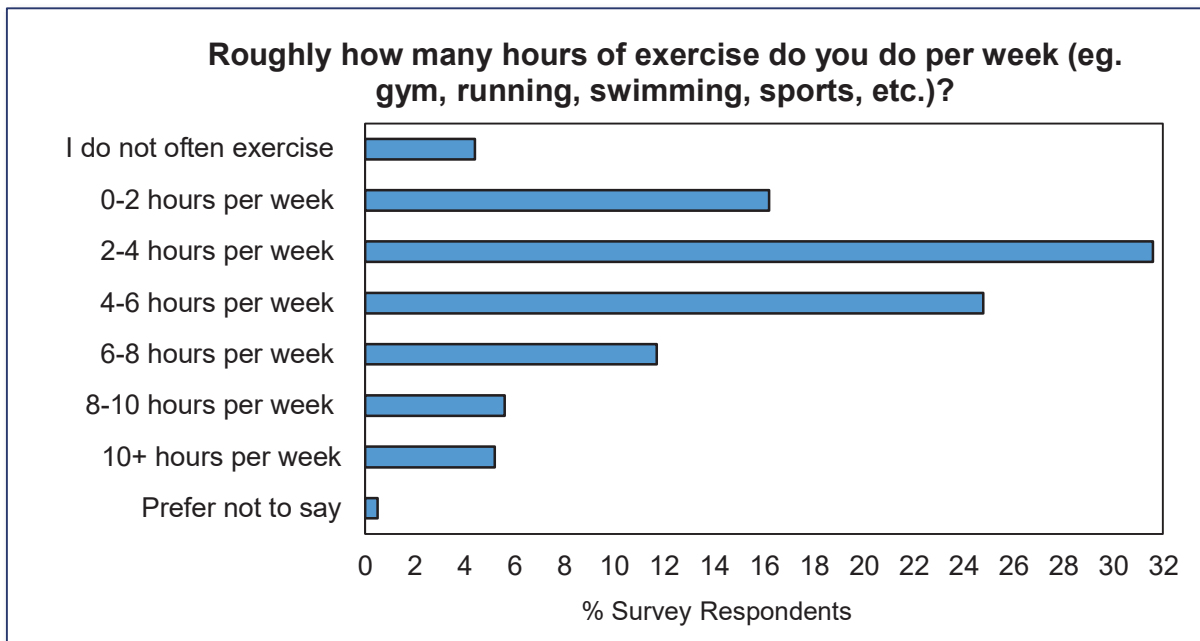


Figure 10: % of Respondents to the FBU & UCLan National Firefighter survey who indicated the number of hours of exercise they did per week. According to recent YouGov studies, on average, about 62% of Britons manage only a single 30 minute exercise session a week (Smith, 2020).

In the US, it was found that 45% of on-duty deaths among US firefighters were caused by **coronary heart disease** (heart diseases, heart attacks, stroke and congestive heart failure) (Kales et al., 2003). Researchers have shown that exposure to cardio-toxic substances such as hydrogen cyanide, carbon monoxide or particulate matter may accelerate vascular disease. Increased risk of heart attacks leading to death may also be caused by heat stress, exertion, dehydration, shift work, stress-related to responding to fire calls or the physical demands of the tasks encountered at the incident (T. Guidotti, 2014). Other studies show a direct link between high blood pressure (hypertension) and diabetes (blood sugar too high), cholesterol, and lack of physical fitness (Kales et al., 2003; Maqbool et al., 2018).

61% of UK serving firefighters who responded indicated they have problems with their sleeping.
(FBU & UCLan National Firefighter survey)

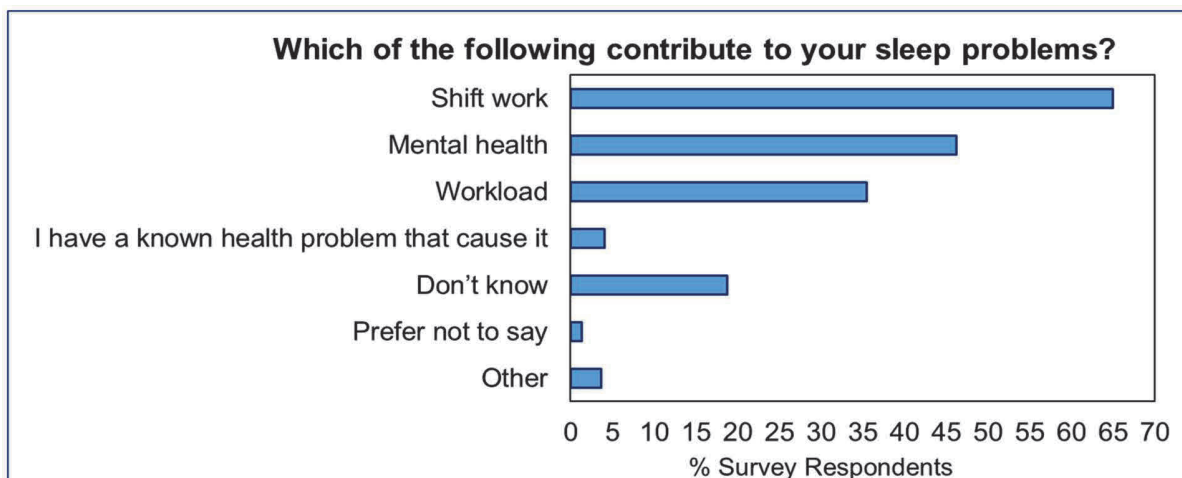


Figure 11: % of Respondents to the FBU & UCLan National Firefighter survey who listed factors contributing to their lack of sleep. 61% of National Firefighter survey responders indicated problems with their sleeping.

During simulated firefighting activities, a majority of firefighters may lose over 1% of body weight in fluid loss, enough to affect mental function, strength, and dexterity.

(Walker et al., 2016; Woodbury & Merrill, 2019, Horn et al., 2012)

Heat stress, heat exhaustion and heat stroke resulting from prolonged and frequent exposures to high temperatures, especially in full protective gear, can not only lead to hyperthermia (core temperature >40.5 °C), but also dehydration, which can exacerbate **heart, kidney, liver, and gastrointestinal tract diseases** (Cheshire, 2016, Shaw & Tofler, 2009). The physical demands of firefighting and the high temperatures in which firefighters operate can lead to profuse sweating. Heavy and thick personal protective clothing restricts cooling, making sweating ineffective, disturbing the body's thermoregulatory processes and water balance. Recent research involving US firefighters at training exercises has shown that over half of study subjects were dehydrated before beginning firefighting activities (Horn et al., 2012). During simulated firefighting activities, a majority of the studied US firefighters lost over 1% of their body weight in fluid loss, enough to affect mental function, strength, and dexterity. In addition, increased blood flow, sweating rates and body temperature together with the body's reduced water content also increase dermal intake of fire effluents (Walker et al., 2016; Woodbury & Merrill, 2019, Horn et al., 2012). The kidneys are known to be particularly susceptible to damage from environmental toxicants (Vervaet et al., 2017), so a combination of dehydration, coupled with repeated exposure over a number of years, may go some way towards explaining the elevated risk of kidney disease deaths reported (Roncal-Jimenez et al., 2015).

Cirrhosis of the liver may be caused from the long-term exposure to fire effluents.

(Daniels et al., 2014; Haddock et al., 2012)

Information on non-malignant **liver diseases** and non-alcohol related mortality within the fire service is sparse and inconsistent (Daniels et al., 2014; Haddock et al., 2012). There are a number of factors that may affect the digestive systems of firefighters. Increased cirrhosis mortality may come from exposures to chemical toxicants or other infectious diseases, which may also account for acute renal dysfunction (Daniels et al., 2014). It is recognised that long-term exposure to specific components of fire effluent (e.g. acrolein) causes irritation and damage to gastrointestinal epithelial tissue, while other fire effluent components (e.g. PCBs) are associated with histologic changes in the liver (Faroon et al., 2008; Graveling & Crawford, 2010; Kim et al., 2017).

There are already numerous amounts of research into firefighters' deaths from diseases of the **central nervous system (neurological disorders)**. However, data (standard mortality rates)

Central Nervous System or neurological diseases have also been positively linked to long-term exposure to fire effluents.

(Abou-donia et al., 2016; Tang et al., 2003; Wood, 2016)

vary significantly between those studies (Beaumont et al., 1991; Jalilian et al., 2019; LeMasters et al., 2006; Pukkala et al., 2014). Motor neurone disease (MND) occurs when motor neurone cells progressively stop working effectively. Causes include genetics and exposure to environmental toxicants. Chemicals thought to contribute to this disease include certain metals (lead, mercury, aluminium, cadmium, chromium), benzene, formaldehyde, polychlorinated biphenyls, polychlorinated (or brominated) dibenzodioxins and furans (Ash et al., 2017; Peters et al., 2017; Steenland et al., 2006; Sutedja et al., 2009). More recently, exposure to environmental neurotoxins such as PBDEs or halogenated organophosphorus flame retardants (commonly used in furniture or insulation materials), have also been positively linked to various neurological disorders (Abou-donia et al., 2016; Tang et al., 2011; Wood, 2016). It is suggested that diesel exhaust emissions might also be a risk factor for these disorders (Dickerson et al., 2018). Central nervous system neuron regeneration may also be affected by heavy work load or stressful activity that reduces sleep quality and melatonin levels (Cherry, 2002).

A high number of studies show that frequent, prolonged and direct exposure to smoke elevates breathing rates, resulting in deposition of smoke particles in the **respiratory tract**. It is known that fine particles can be one of the best single indicators for the impact of combustion product inhalation on lung health (Swiston et al., 2008). Studies have suggested that exposure of lung epithelial cells to fine particles promotes inflammation due to alveolar macrophage response (Hiraiwa & Eeden, 2013). This may contribute to the increased incidence of chronic respiratory diseases within firefighters. Exposure to wood smoke (through exposure without proper use of sufficient breathing apparatus at wildland fires, or in the case of instructors not wearing breathing protection at firefighter training exercises) is found to have a marked effect on the respiratory immune system and at high doses can produce long-term or permanent lesions in lung tissues. These effects seem most strongly associated with the respirable particle size range that is thought to be most damaging to human health (Naehler et al., 2007).

In one recent UK pilot study, it was suggested that repeated exposure to high temperatures may adversely affect the **immune system** of firefighters (Richardson, n.d.). Typically, the most common sites of infection are lungs (pneumonia), urinary tract (kidney), and abdomen (peritonitis, appendicitis) (Ross et al., 2018). This raises the question of whether these deaths indicate that firefighters have an elevated risk of dying from infection.

Due to the large gender disparity in fire services globally there is very limited evidence concerning the health effects of firefighting activities and exposure to contaminants in female firefighters.



CONTAMINATION: CONTROLLING AMOUNT AND EXPOSURE TO TOXINS

Contamination Types

The inherent toxicity of fire effluent components cannot be controlled. Neither can the inherent physical properties of these effluents, which make certain exposure pathways viable. However, what **can** be controlled to some extent is the **amount** (or “dose”) of fire effluents which firefighters are exposed to. Personal protective equipment (PPE) is designed to protect firefighters by reducing or completely restricting the amount (dose) of toxic effluents firefighters are exposed to via multiple exposure pathways (see “Contaminants, Toxicity and Exposure Pathways” and “Personal Protective Equipment” sections).

However, when PPE or equipment becomes **contaminated** it loses its efficacy at protecting firefighters against exposure to toxic fire effluents. In fact, contaminated PPE may even *increase* the dose of toxic fire effluents firefighters are exposed to.

The most common types of contamination are summarised below (National Operational Guidance (NFCC), 2020):



Figure 12: An example of surface contamination

Surface contamination occurs when contaminants are present on the outer layer of a material but have not been absorbed into the material (e.g. Figure 12). Surface contaminants are usually easy to detect and easy to remove to a reasonably achievable and safe level (dust, fibres etc.).

Permeation of contaminants occurs when contaminants are absorbed *into* a material (e.g. Figure 13). If not removed, contaminants may continue to permeate further through the material. Factors that influence permeation include:

- *Temperature*; increased temperatures generally increase the rate of permeation. Conversely, lower temperatures will generally slow down the rate of permeation – as temperature changes the physical properties of contaminants (e.g. increasing temperature may increase the viscosity of liquids, or vaporise contaminants to gases, which are then able to flow more freely into materials). Increasing temperature may also alter structure of materials – making it easier for contaminants to pass through.



Figure 13: An example of contaminants permeation

- *Contact time*; the longer a contaminant is in contact with an object, the greater the probability and extent of permeation.
- *Concentration*; molecules of the contaminant will flow from areas of high concentration to areas of low concentration. Generally, the greater the concentration, the greater the potential for permeation to occur.
- *Chemical and physical properties*; gases, vapours and low-viscosity liquids tend to permeate more readily than high viscosity liquids or solids.

Permeated contaminants are often difficult or impossible to detect and remove. Permeation through protective clothing could cause exposure inside the suit.



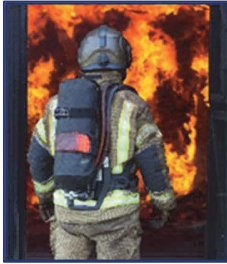
Figure 14: An example of direct contamination

Direct contamination occurs via direct physical contact with a contaminant or any contaminated object (during the fire incident, the turning over process or the decontamination process). Helmet, gloves and boots are the most common areas that get directly contaminated. Both surface contamination and permeation can occur through a direct contamination pathway.



Figure 15: An example of cross contamination

Cross (or secondary) contamination occurs when a person or object that is already contaminated makes contact with a person or object that is not contaminated and subsequently contaminates that person/object (National Operational Guidance (NFCC), 2020) (e.g. storing contaminated gloves within a clean helmet). Both surface contamination and permeation can occur through a cross contamination pathway.



Personal Protective Equipment

Firefighters' fire gear is not designed to prevent combustion gas particles from coming into contact with the body (Swedish Civil Contingencies Agency, 2015).

In line with HSE regulations on personal protective equipment (PPE) at work, all users should be trained on the use and limitations of each type of protective clothing that is provided. In the UK, firefighters' PPE (helmet, tunic, leggings, gloves, boots and respiratory protection) must conform to BS EN 469:2005 for performance requirements (heat resistance, surface wetting, resistance to water penetration, heat transfer from flame and radiation, etc.) (British Standards Institution, 2006). However, **there is currently no UK requirement for PPE to protect against toxic gases and particulates.**

Firefighter's protective clothing shall be designed to provide protection for the firefighter's torso, neck, arms to the wrists, and legs to the ankles during firefighting (British Standards Institution, 2020). Where protection is provided by a two-piece suit, it shall be determined that an overlap between the jacket and trousers shall always be retained. In addition, the wrists and ankles shall remain covered when wearing appropriate sized clothing in an upright position (British Standards Institution, 2020). All external pocket flaps shall be stitched down or capable of fastening the pocket closed. All pockets in the garment shall be designed in such a way to prevent entry of heat, flame, or hot material, exception for external radio pockets (British Standards Institution, 2020).

The biggest suppliers of PPE in the UK are Ballyclare and Bristol - which both provide managed options for monitoring and laundering PPE, as well as for inspection of garments for damage or loss of functionality – although it should be noted that not all FRAs choose this option.

NOTE: In the US, the fabric of the fire hood must block 90% of particulates (between the size of 0.1µm and 1.0µm) according to US NFPA (ASTM International, 2017; Lee et al., 2015; National Fire Protection Association, 2018). These particle-blocking fire hoods are beginning to enter the UK market, and may become more popular in the future, potentially influencing a change in protection standards for UK PPE.

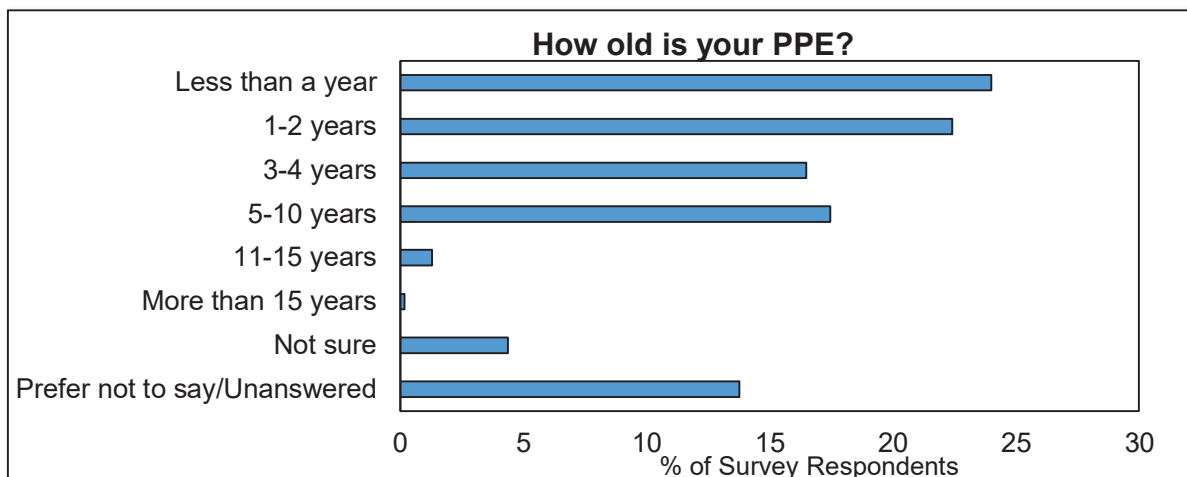


Figure 16: % of Respondents to the FBU & UCLan National Firefighter Survey indicating the age of their PPE.

The replacement cycle for fire kit can be relatively long (Figure 16), which means that the clothing may be subjected to repeated and regular contamination during its service life and may no longer be able to effectively perform its protective function from toxic contaminants (references below). It has been shown that organic contaminants can be transferred from the fabric of PPE to the skin. These contaminants can then penetrate deeper dermal layers, with the potential for systemic toxic effects i.e. effects which target multiple sites of the body (Burke & Sparer, 2018; Fent et al., 2013; Ladaresta et al., 2018; Stec et al., 2018). This decreased functionality of PPE garments can occur before the garment appears visibly damaged to the naked eye (Rezazadeh & Torvi, 2011).

Exposure to fire effluent via contaminated PPE most commonly occurs:

- During removal and storage of contaminated PPE (Fent et al., 2013).
- During PPE gassing-off (in vehicles, and non-work environments by hanging up heavily contaminated PPE in a room without ventilation or during drying (Fent et al., 2017; Harrison et al., 2018; Rogula-koźłowska et al., 2018).
- When transferring contaminants from contaminated PPE to workwear and/or directly to the skin during washing (Harrison et al., 2017).
- Via cross contamination with clean garments during domestic laundering cycles (Mayer et al., 2019; Stapleton et al., 2005).



Helmet

Due to its function and design, the helmet can become contaminated on both inside and outside surfaces. As it is worn on the head it has very close contact with both skin and airways. Ideally, helmets should have removable soft goods (cradle) which can be separated and more thoroughly cleaned (according to manufacturers' recommendations).



Fire Hood (Flash Hood)

Many fire hoods fail to provide a barrier against superfine particles and soot, which absorb a variety of hazardous chemicals including carcinogens.

It is recommended that fire hoods should be washed immediately after return to the station, after every fire incident. This is because:

- Protective fire hoods are in direct contact with the skin during a fire incident.
- Sweat allows contaminants to pass through the fire hood and onto skin more efficiently.
- Dermal absorption rates for the relatively thin skin on the scalp, forehead, jaw and behind ears are much faster than the dermal absorption rates for thicker skin on e.g. palms of hands.
- The face and neck have been identified as areas at significant risk of dermal exposure to products of combustion and potential carcinogens (Stec et al., 2018).

The skin's permeability increases with temperature.
For every 5°C increase in skin temperature, absorption of toxins via skin
increases 400%.

(Firefighter Cancer Support Network, 2013)

NOTE: Further research is required to verify these figures. However, a number of other studies have found that increasing skin temperature leads to an increase in skin permeability (Park et al., 2008; Jones et al., 2003). Absorption of contaminants through the skin is likely increased by temperature via enhanced blood flow to the surface of the skin, increased skin hydration due to sweating, and the opening of skin pores (Jones et al., 2003). A study of Italian military firefighters found that skin temperature increased by an average of 10% during firefighting activities (Del Sal et al., 2009). This is roughly in agreement with previous studies (reviewed in (Barr & Gregson, 2010). For example, Romet and Frim (1987) found skin temperature to rise from 34.5 to 37.4 °C during the most demanding firefighting activities (Romet & Frim, 1987).

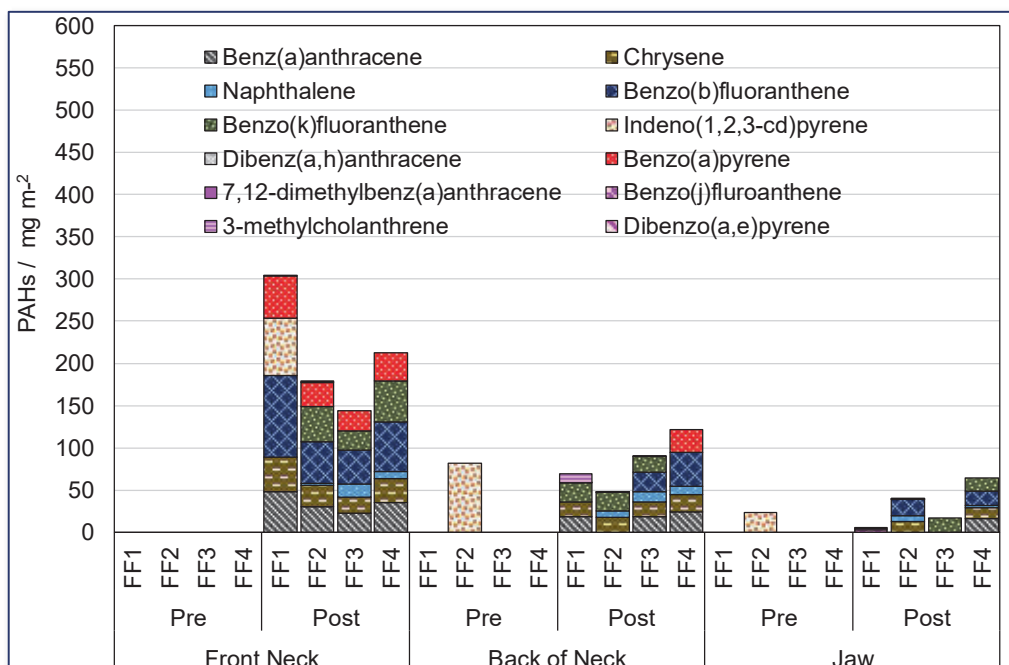


Figure 17: Concentrations of toxic PAHs, collected from the front and back of the neck and jaw. Samples were collected pre- and post-exposure from an instructor (FF1) and three trainees (FF2-FF4) attending training (Stec et al., 2018).

Fire Gloves



Figure 18: Example of common, but **not recommended** practice, whereby fire gloves (which are subject to considerable contamination) are stored in helmets – leading to cross contamination.

Fire gloves must meet the requirements of BS EN 374-3 and selection should be made according to the hazard encountered. A dual glove system may afford the best protection (British Standards Institution, 2003). This normally consists of a laminated inner glove having good chemical resistance with an outer elastomeric glove affording protection against mechanical abuse as well as having some degree of chemical resistance.

Firefighters' protective gloves are probably the clothing that is most subjected to contamination. It is the item which is the most difficult to wash and dry simply and effectively whilst retaining its shape and function. Firefighters' gloves are often made with leather or leather-like material, meaning they are sensitive to machine-washing. They also have a tendency to lose their shape if they are cleaned and dried carelessly.

Since gloves and fire hoods differ considerably from one Service to another, personnel should be made aware of the most appropriate cleaning guidelines for the type of PPE provided.

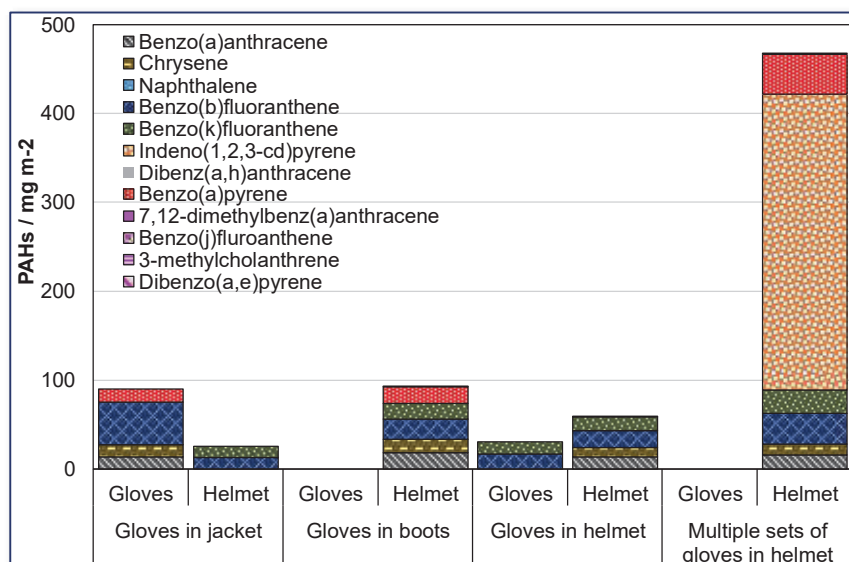


Figure 19: Concentrations of toxic PAHs on PPE clothing, stored in different configurations (Stec et al., 2018).



Respiratory Protection

Respiratory protective equipment in the workplace is divided into two main types (Health and Safety Executive, 2013):

- **Breathing apparatus** – Worn where there is an irrespirable and/or contaminated atmosphere. This needs a supply of breathing quality air from an independent source (e.g. air cylinder or air compressor)
- **Respirator (filtering device)** – This uses filters to remove contaminants in the air. They should never be used for protection in fire situations or where there is any possibility of reduced oxygen levels. They should always be subject to appropriate face-fit assessment.

A Respirator (filtering device) must never be used in place of a compressed air breathing device (SCBA or airline).



Breathing Apparatus

Studies by National Institute for Occupational Safety and Health (NIOSH) show that even self-contained breathing apparatus (SCBA) worn and evaluated as fully operational becomes contaminated within 25 minutes of use in firefighting situations (Fent et al., 2013). These results signify that there is a build-up of toxicants (e.g. PAHs, VOCs) within firefighters' ensembles (jacket, leggings, boots, helmet, fire hood, fire gloves etc.), especially with repeated use. This results in increased toxic exposure to firefighters from just their ensemble (Alexander, 2012; Baxter et al., 2014; Kirk & Logan, 2015).

**Firefighters are often tempted to prematurely remove breathing apparatus
(without replacing it with any other form of respiratory protection)
so that they can move more effectively.
(FBU & UCLan National Firefighter survey)**

- Selecting an effective respirator and filter is not always possible, as firefighters will rarely know what specific contaminants are present at fire incidents. In these situations, breathing apparatus better protects firefighters from unknown and/or undetected toxins in smoke.
- Maintenance, examination and testing of compressors for BA should be carried out according to the manufacturer's instructions.
- Air compressors can generate and concentrate a wide range of contaminants, therefore extra care in assuring air quality should be taken.

NOTE: Across the US there are an increasing number of purpose-built machines to decontaminate PPE and SCBA. These machines are not currently widespread across the UK albeit we are aware UK FRSs are starting to consider this option.

BA should not be removed prematurely or donned too late.

Respirator (filtering device)

Specialists have developed criteria for the selection of proper, adequate respirators. One of these criteria is the "Assigned Protection Factor" (APF). The APF is a number rating that indicates how much protection a respirator is capable of providing. For example, respiratory protective equipment with an APF of 10 will reduce the wearer's exposure by at least a factor of 10 if used properly, or, to put it another way, the wearer will only breathe in one-tenth or less of the amount of contaminant present in the air (Health and Safety Executive, 2013). A summary of available respirators is provided in Table 4.

- **Particle filters.** Certain respirators are fitted with particle filters, which trap particles present in the air (e.g. dust, mist, fume, smoke, micro-organisms). However, these filters **do not** trap gases or vapours, organic liquid mists and sprays, or give any protection against oxygen-deficient atmospheres. Some manufacturers may recommend the use of pre-filters (coarse filters) to protect the main filters.



Particle filters are assigned one of three ratings, depending on their filtration efficiency; FFP1, FFP2 or FFP3 (Table 3; where FFP stands for “*filtering face piece*”, sometimes simply abbreviated to “P” as in Table 4). If the filter is compatible for use with a fan-assisted respirator, it will also be marked with the symbol “TH” or “TM”. If a colour coding system is used, particle filters will bear a white label. Respirators fitted with particle filters should only be re-used if they are specifically indicated as re-useable.

Filtration Efficiency Rating	Protection Level against dust, solid and liquid aerosols	Filter Capacity % removal of particles $\geq 3 \mu\text{m}$	Occupational Exposure Limit	APF
FFP1	Low	At least 80%	4x	4
FFP2	Moderate	At least 94%	12x	10
FFP3	High	At least 99%	50x	20

Table 3: The filtration efficiency ratings assigned to particle filters and the relative levels of protection they provide. These filters are assessed against a “safe” level of exposure known as an “Occupational Exposure Limit”. The table indicates how many times over this limit the level of particulates can be while particle filters are still able to protect wearers

- **Gas/vapour filters** are designed to remove gases or vapours as specified by the manufacturer. They do not protect against particles, or oxygen-deficient atmospheres. These filters have a limited capacity for removing gases/vapours, so after some time the gas or vapour will begin to pass straight through the filter and into the wearer’s respiratory system (Health and Safety Executive, 2013).

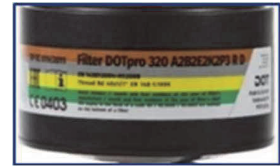
Gas/vapour filters are usually divided according to the type of substance they provide protection against. Filters are marked with a letter to indicate type of substance, and a number to indicate the filter's capacity, and comply with a standard colour coding system (Table 4) (Health and Safety Executive, 2013).

Caution: The capacity of a filter is assigned based on laboratory testing under well-controlled conditions. Therefore, this capacity may not always be an accurate indicator of the filters' performance under uncontrolled conditions in the field – where some substances may permeate the filter before the assigned capacity is reached.

RESPIRATOR FILTERS		
Colour Code	Filter Type	Contaminants Protected Against
	P	Particles
	A	Gases and vapours of organic compounds with boiling point > 65 °C
	AX	Gases and vapours of organic compounds with boiling point < 65 °C
	B	Inorganic gases and vapours, e.g. hydrogen cyanide, chlorine, etc.
	E	Sulphur dioxide, hydrogen chloride
	K	Ammonia and organic ammonia derivatives
	CO	Carbon monoxide
	Hg	Mercury vapour
	NO	Nitrous gases including nitrogen monoxide, nitrogen dioxide
	Reactor	Radioactive iodine including radioactive methyl iodide

Table 4: Standard colour coding system for respirator filters

- **Multi-gas filters** contain filters for more than one type of gas or vapour. The types of gas/vapour these filters protect against along with their capacity are marked as above (e.g. A1B2 filters protect against organic vapour with capacity class 1 and inorganic gases with capacity class 2). Multi-gas filters are heavier, and harder to breathe through in practice. These filters must be checked against the manufacturer's instructions on proper use and replacement intervals.



NOTE: If performance against mixtures of gases is needed, it may be safer to consider using breathing apparatus.

- **Combined filters** are designed against both particles and specific gases or vapours. This type of filter will carry markings for particles and vapours, e.g. A2P3 filters protect against organic vapours with a filter capacity of class 2 and high efficiency for filtering out particles (Health and Safety Executive, 2013).

Respirator (filtering device)						
	Disposable half mask:	Reusable half mask:	Reusable half mask:	Full face mask,	Full face mask:	Powered (fan-assisted) hoods/helmets
	particle filter	half mask particle filter	gas/ vapour filter	particle filters	gas/vapour filter	Powered (fan-assisted) masks
						
Effective for particles	V	V	X	V	X	V*
Effective for gas/vapour	X	X	V	X	V	V*
APF4 types	V	V	X	V	X	X
APF10 types	V	V	V	V	X	V
APF20 types	V	V	X	X	V	V
APF40 types	X	X	X	V	X	V
Continuous wear time	Less than 1 hour	Less than 1 hour	Less than 1 hour	Less than 1 hour	Less than 1 hour	More than 1 hour

Table 5: Summary of the most common filtering devices (respirators) (Health and Safety Executive, 2013) *Only protects against particle or gas/vapour when the appropriate filter is fitted.



Appliance and Appliance Bay

Appliances and other vehicles can be contaminated both externally (during the fire incident) and internally (via contaminated PPE and equipment).

Manufacturers of emergency vehicle apparatus have been actively designing new and improved decontamination enhancements. Some of these features include:

- Inclusion of automated dispensing of disinfectant inside the cab, thus reducing emergency responders' exposure to harmful pathogens.
- HEPA air filtration systems (removing contaminated particles).
- Creation of non-SCBA seats to help prevent contamination from BA sets entering the cab.
- Seat surfaces that enhance a cleaner environment inside the cab (i.e. easy to wipe down).
- External compartments to store SCBAs on a pull-out locker for easier access and/or for the storage of fire kit with exterior access only.

Allowing the appliance or any other vehicle to idle in the appliance bay must be avoided (both when the appliance bay doors are still shut and/or appliance doors are opened)

NOTE: *this practice was observed when visiting UK FRS stations for indoor contaminant testing and in the FBU & UCLan National Firefighter survey.*



DECONTAMINATION

Decontamination is a process defined as:

“The removal of hazardous substances (bacteria, chemicals, radioactive materials) from employees’ bodies, clothing, equipment, tools and/or sites to the extent necessary to prevent the occurrences of adverse health and/or environmental effects.”
(Business Dictionary, 2020).

The key phases of a decontamination procedure consider decontamination en-route to an incident, at a fire incident, en-route back to the fire station, and at the fire station itself. These phases exist in a cycle (Figure 20). Examples of good fire effluents decontamination practice can be found in the Appendix.

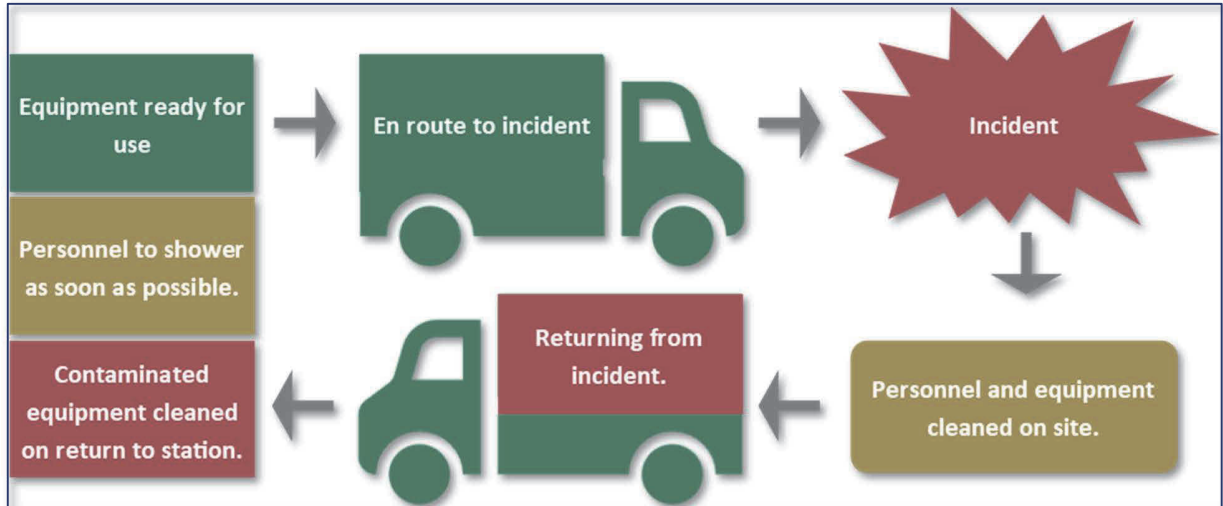


Figure 20: The decontamination cycle (adopted from Swedish Civil Contingencies Agency, 2015).



FIRE INCIDENT: MINIMISING CONTAMINATION

It should be ensured that all FRS staff arriving at an incident have effective personal protective equipment and are adequately trained and briefed for the work they are to undertake within the cordon. At all stages of the decontamination procedure the Incident Commander must consider the safety of FRS personnel, the public, members of other emergency services and voluntary agencies attending incidents.

All Services should have procedures in place which detail how exposure to fire effluent and debris will be minimised en-route to, during and after incidents.

A decontamination procedure is a prescriptive set of steps which must be carefully planned and followed to ensure a thorough, safe and successful decontamination process. The specific steps of a decontamination procedure will vary according to the type of incident etc. However, the steps of a **generic** decontamination procedure should be **fully risk assessed** and should include:

1. Pre-planning; this step should ensure:

- All required risk assessments are in place.
- All operational crews are fully trained and familiar with decontamination guidance and are able to implement decontamination procedures.
- Tools required for decontamination procedures are accessible following any fire incident.
- Workplace facilities are prepared for further decontamination procedures once back from the incident.
- A risk-assessed waste disposal procedure is in place for contaminated waste.
- Decontamination procedures are available and accessible such that they may be read-out during the decontamination process or may be provided as e.g. a pictorial walkthrough of the decontamination and safe undress process.
- Sufficient personnel to implement the plan.

2. **Briefing**; i.e. briefing personnel and firefighters e.g. on potential hazards and appropriate conduct of decontamination methods.
3. **Designating decontamination areas and zones**; identifying suitable locations in which to safely carry out decontamination procedures which minimise risk of re-contamination.
4. **PPE decontamination**; reducing or removing contamination from external surfaces or layers of PPE e.g. using dry and/or wet methods.
5. **De-robing**; safely removing external layers of personal protective equipment or chemical protective clothing.
6. **Checking for remaining contamination**; examining PPE for visible contamination, or contamination risks e.g. gaps or tears in the clothing etc.
7. **Personal decontamination**; washing hands, face and any other exposed areas of the body with soap and water, wipes etc.
8. **Dressing**; safe dressing and welfare considerations e.g. hydration, rest, food.
9. **Recording**; i.e. documenting any specific exposures, levels of exposure, exposure risks etc.
10. **Managing contaminated PPE**; safely storing and managing transport of PPE and equipment back to the fire station.
11. **Follow up**; conduct more thorough PPE and personal decontamination on return to the fire station e.g. laundering, showering etc.

Decontamination procedures should emphasise thoroughness, not speed.

Minimising Contamination at Fire Incidents

Poor and ineffective decontamination procedures can lead to unnecessary exposure to toxins. Listed below are some good general practice recommendations on arrival and at the fire incident scene which should be considered for incorporation into decontamination procedures:

En route

- Appliance windows, doors and air vents should be closed on approach to an incident.
- If possible, fire crews should be briefed on potential combustion products released in the fire (and types of materials involved in the fire) before arriving at the incident.

On-site

- Incident commanders and crew should position appliances at a safe distance away from the hazard ('hot') zone.
- Personnel should be positioned upwind of an incident, wherever possible.
- Contact with obviously contaminated areas should be limited where possible, avoiding areas that contain potentially hazardous materials.
- If possible, contaminated areas should not be knelt in or laid in unless immediate personal safety requirements makes this unavoidable
- Direct contact with the face/mouth should be avoided while on-site.
- The preferable method of consuming liquids is by means of a squeeze bottle with an attached drinking tube as used by athletes (limiting contact with face/mouth).
- Full personal protective equipment, including SCBA, should be worn **at all times** (including during fire and turning over). This is absolutely crucial for protecting firefighters against inhaling toxicants.



Full PPE and appropriate respiratory protection must be worn throughout the entire incident, including during salvage and turning over.

- PPE should fit well, and should ideally have been fitted for the individual wearer by the provider. There should be adequate overlap between all garments, ensuring that no part of the body is exposed.
- Respiratory protection should be worn in line with the manufacturer's instructions and in accordance with local risk assessments – it should fit well and, where appropriate, form an airtight seal around the wearer's nose and mouth.
- Clothing and PPE should be correctly fitting, correctly worn and clean, to reduce the potential for dermal exposure from previously soiled garments. This includes tunics, leggings, fire hoods, gloves and base layer.
- A filter mask should be easily and quickly available for sudden emergencies.
- Gloves should be worn when making up the hose/equipment.
- Moisture wicking undergarments should be worn beneath PPE. This will help ensure the wearer does not overheat, and will help reduce dermal absorption of toxicants.
- Cotton liner gloves worn under fire gloves may help to reduce exposure to debris, as well as reducing irritation due to sweating or heat.



NOTE: Reducing exposure to fire debris and effluent should be considered important, but should not be done at the detriment of thermal protection or adequate hydration. Fatigue should not come as a result of decontamination. Rather, decontamination should be worked into the standard routines at the fireground, and should be accounted for when evaluating rest periods.



RETURN TO THE WORKPLACE FROM FIRE INCIDENTS

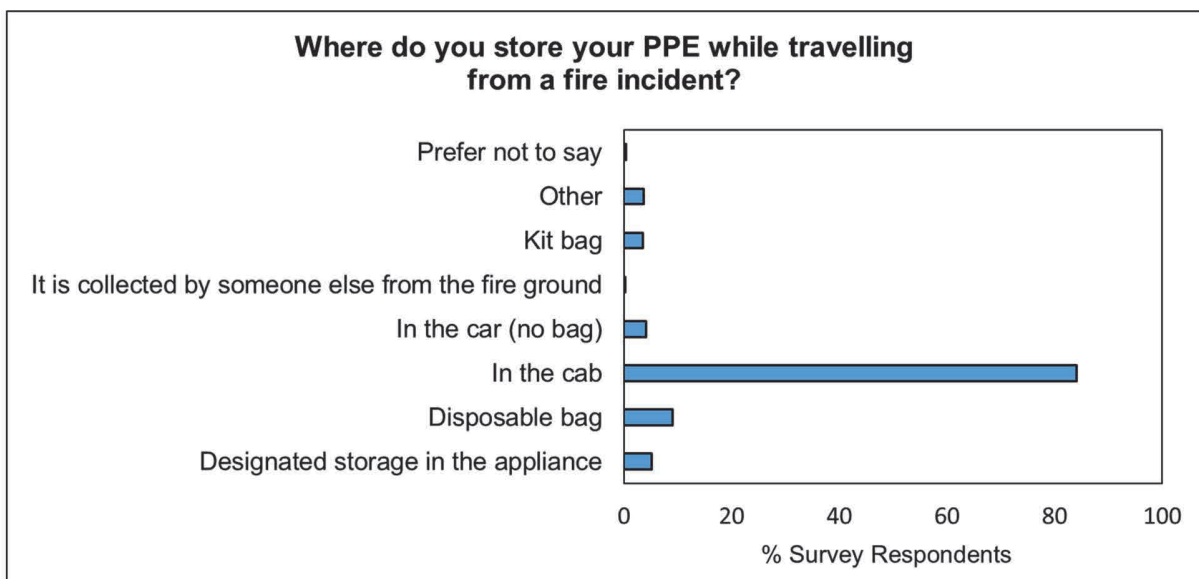


Figure 21: % of Respondents to the FBU & UCLan National Firefighter survey who indicated that the most prevalent current practice is to store PPE in the cab of a vehicle or appliance.

- Contaminated PPE and equipment should be cleaned on site wherever possible, **prior to transportation** while using respiratory protective equipment. If this is not possible, all PPE (such as tunic, leggings, helmet, gloves) should be bagged at the scene (in bags of at least 6 mm thickness which are then twisted and taped/knotted shut to minimize secondary exposure to any contaminants gassing off). All bags should be secured outside of the fire appliance cab in a locker.

- Soiled PPE should be stored should be placed into appropriate containers/bags to prevent cross-contamination. Water-soluble bags (approved for use in the laundry process) or other similar bags should be used for this purpose. If PPE is wet, the water-soluble bag should be placed into another container/bag to prevent cross contamination in the event that the water-soluble bag starts to dissolve.

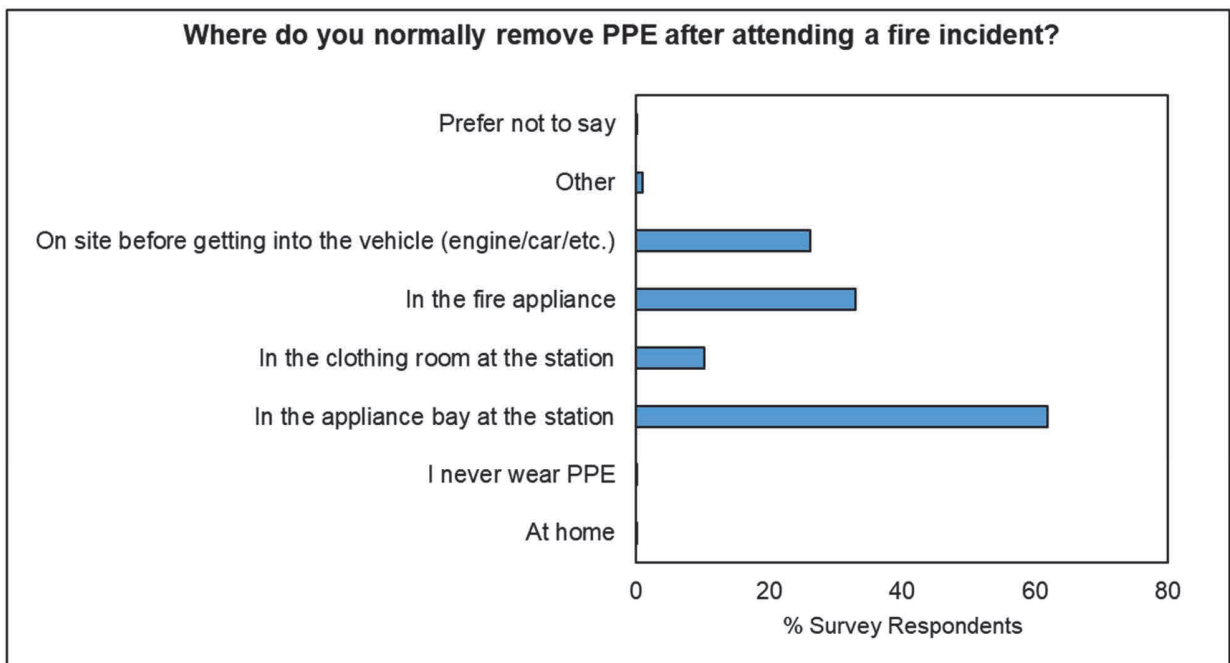


Figure 22: % of Respondents to the FBU & UCLan National Firefighter Survey indicating that the most prevalent practice is to remove PPE at some point after re-entering the appliance. Participants were able to choose more than one answer to this question.

- Soiled BA kits and any other equipment (such as thermal imaging cameras, radios etc.) **should not be stored** in the appliance or vehicle cab. If they must be stored in the cab they should be cleaned prior to transportation (according to manufacturer's recommendations).

It is strongly advised that FRSs encourage all operational personnel to record and monitor their attendance at fire incidents over the course of their career.

- Contaminated hose should be placed in an airtight storage device in the same way as fire kit and respiratory protection in order to reduce the amount of volatile effluents and particles spread during transportation and handling.
- It is a common practice to clean the exterior of a helmet to remove any heavy particulate. However, when cleaning the interior, care must be taken not to saturate any fabric, including the liners. Interiors can be wiped down with wipes. They may be washed with soapy water only according to manufacturer's instructions.
- Boots often have deep tread soles which trap dirt and waste from the fire ground. A boot which is not decontaminated therefore functions as an effective spreader of contamination.
- All personnel should wash their hands, head, neck, jaw, throat, face, and any other exposed skin areas as deemed necessary with soap and water. Where this is not practical, wipes should be provided as a minimum. This should not be considered a substitute for a thorough shower (within an hour) on return to the station.
- All personnel should have a clean, dry change of clothes which is taken to every incident. Personnel should change into clean clothes **before re-entering the appliance** (Figure 22). This avoids a rapid decrease in body temperature and reduces skin exposure to contaminants through sweat and water that dries on the workwear. If this is not possible or suitable, undergarments should be changed as soon as possible on return to the station.



Wipes may be effective, but do not replace a shower.

“Shower within an hour” when returning to the station from an incident, or a live fire training exercise.



FIRE STATION: CONTAMINATION CONTROL

Recent research findings show that debris and contamination from fire is transferred back to fire stations, resulting in continual exposure of firefighters to potentially harmful toxicants (see Section “Additional considerations for FRS personnel responding in their personal or FRS provided vehicles vehicles” for consideration of exposure to contaminants away from the fire station). In fire stations, higher concentration levels of carcinogens, such as PAHs, phosphorous flame retardants and polybrominated diphenyl ethers (PBDEs, organobromine compounds that are used as flame retardant) in air, debris and dust samples were identified when compared to workplaces not associated with fire. They were particularly found in more soiled areas of stations, with “dirty” areas such as BA rooms and PPE storage areas. One study has identified PAHs in kitchens and appliance bays in stations (Baxter et al., 2014, Shen et al., 2015, Shen et al., 2018).

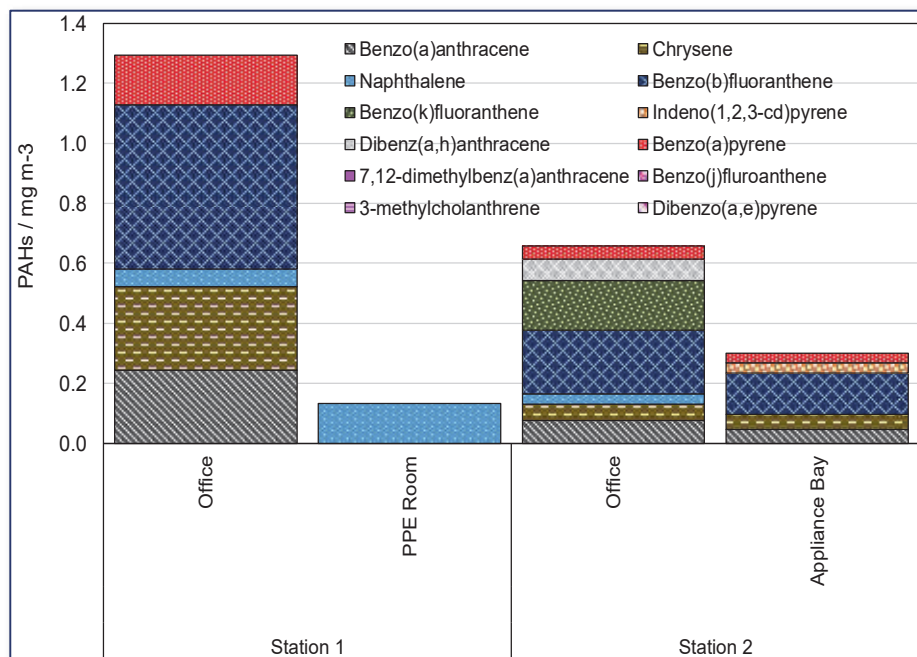


Figure 23: Concentrations of toxic PAHs collected from two stations showing contamination in the general use offices, PPE storage room (with internal ventilation) and appliance bay (Stec et al., 2018).



Designated Zones

It is important to control the spread of harmful substances on return to the fire station, prior to further decontamination and repair. This can be achieved by the designation of “contamination zones” at the fire station, similar to the designation of decontamination zones at the fire incident (Table 6).

	Hazard level	Locations	Function
Red zone	Dirty area	Appliance bay Appliance washdown Operational washdown Workshop Operational equipment store Compressor room Dirty kit collection Briefing/debrief room	These are primarily operational areas. Ideally, there should be a decontamination at source policy, but the red area has a medium risk of cross contamination or exposure to carcinogens. If leaving a red area, staff should not be able to enter a green area without passing through a transitional zone (amber) with the opportunity to wash and change clothes.
Amber zone	Transitional area	WC/showers Lockers Laundry In-use kit room Drying room / cabinet BA servicing / wash area General equipment store Cleaners' store	A transitional space between red zones and green areas where firefighters and staff can clean and remove contamination. The risk of exposure to contamination or carcinogens is low. Firefighting kit can be worn in this area if suitably clean.
Green zone	Clean area	Public entrance Reception Community room Public WC Personnel main entrance Meeting rooms and offices Quiet rooms / prayer rooms Briefing / training room Recreational rooms Mess area / kitchens Bedrooms / Dormitories Gym IT Comms rooms	Clean areas within a station where food is prepared or consumed and clean only tasks are carried out. I.e. office tasks. No firefighting kit is to be worn and there should be no risk of exposure to contamination from carcinogens.

Table 6: Designation of contamination zones within the Fire Station. Designating contamination zones will depend on the layout and needs of the individual station. Where it is impossible to separate red and green zones by a transitional amber zone (e.g. due to station layout) a risk assessment and guidance must assess how contamination will be managed in those areas.



The following should be considered and accounted for when designating contamination areas within the fire station:

- How contaminated clothing and equipment is moved or transported within the workplace should be looked at in detail.
- Every effort must be made to ensure clean areas (areas where personnel spend time when not responding to an incident) are kept free of any contaminated clothing or equipment.
- It should be clear to personnel which designated zone they are in, e.g. clean or dirty, through the use of signage, or colour-coded feature walls, floor markings etc.
- Any area where PPE or equipment must be taken, such as PPE rooms and BA servicing areas, must be clearly marked, and kept clean.
- The amount of spent time in enclosed “dirty” areas of the station, such as PPE storage spaces and BA cleaning rooms, must be kept to a minimum.
- The layout of the station should permit safe and efficient movement when responding to a call-out, but must discourage the movement of staff from clean to dirty areas without first passing through a transitional (amber) area.
- Direct and un-obstructed paths of travel into the Appliance Bay must be achievable under emergency response conditions. This ensures response times can be kept to a minimum.
- All personnel should receive training on the contamination zones, and the rationale for their designation.

PPE, drills and operational equipment must be prohibited in “clean” areas (e.g. sleeping areas, lecture rooms etc.), and only allowed within designated “dirty” areas (e.g. appliance bay etc.).

- Existing stock of buildings should be reviewed to maximise the principle of red, amber, green zones.
- Newly designed stations and other FRS buildings should ensure there is only one way for contaminated clothing or equipment to enter the building. They should be planned with “red-amber-green” layout, whereby any entrance place is deemed contaminated, intermediate zones where cleaning occurs denoted as “amber”, and every other area of the station, including all offices, dormitories, mess areas, recreational spaces and training rooms, be kept free of soiled PPE or equipment at all times.



Personal Decontamination

Key notes from UK FRS submitted documents:

Only 22% FRS in the UK provided information regarding personal washing and decontamination following an incident (mostly as FBU guidance displayed on posters).

Personal decontamination should be the top priority upon returning to the fire station from fire incidents.

- Having showers at the fire station is **essential**.
- Adequate shower facilities must be available to all responders, regardless of their gender identity.
- A “**FIRST IN, FIRST OUT**” system should be used if showering facilities are limited, whereby firefighters that have been exposed the longest, in the worst conditions, should clean up and remove the highest amount of accumulated toxins first.

“Shower within an hour” when returning to the station from an incident, or a live fire training exercise.



Contamination Control at the Fire Station

Chief fire officers must enforce PPE/clothing decontamination procedures and ensure all personnel are fully trained and follow the rules (Figure 25).

- Each station should have a cleaning schedule in place to ensure there is no build-up of contaminants in the working environment (on surfaces etc.), and to ensure that PPE/clothing is regularly cleaned.
- PPE must be kept only within allocated PPE storage areas.
- Any area into which PPE or equipment must be taken, such as appliance bays, PPE rooms should be clearly marked, and kept as clean as reasonably possible. BA servicing areas must be kept in a sterile condition.
- Each station should provide or make arrangements to wash base layer garments (clothing worn by firefighters under their PPE) that have been worn to a fire incident.



Figure 24: An example of bad practice – where a mug is left in the vicinity of heavily contaminated PPE.

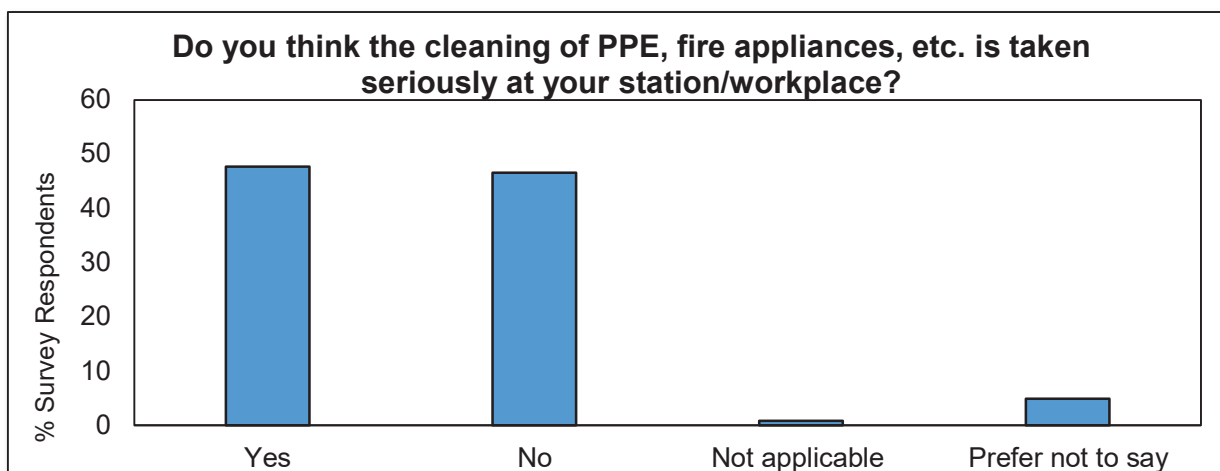


Figure 25: The high prevalence of “no” answers to this question in the FBU & UCLan National Firefighter Survey indicates that decontamination procedures need to be more seriously enforced.

- Drying rooms should be clearly identified as only being suitable for PPE, or only being suitable for non-PPE items such as personal clothing, bedding, towels, etc. – and not suitable for both. The separation of personal items and PPE items is vital for preventing cross contamination.
- Any airtight containers used for transportation of contaminated PPE should be thoroughly cleaned before being reused to prevent a build-up of potential contaminants and potential cross contamination.
- If possible, air quality should be actively monitored – especially where it is impossible for personnel to avoid spending extended periods of time in enclosed “dirty” spaces e.g. BA workshops, facilities without proper ventilation etc.

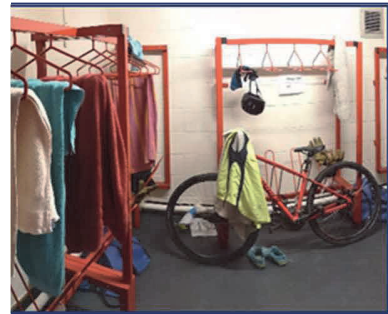


Figure 26: An example of poor drying room set-up.



Decontaminating PPE and Clothing

Below is a list of general considerations for the decontamination of PPE/clothing at the fire station. It is important that every Service puts in place a procedure for sending PPE away for professional cleaning:

- All articles of clothing and/or equipment that were exposed to contaminants should be properly cleaned as specified in BS 8617 (British Standards Institution, 2019).
- Thorough, routine cleaning should include the cleaning of PPE interiors- thus, until the interior of PPE has also been cleaned and dried, the gear should be considered out of service.
- Slightly contaminated PPE e.g. with a slight smell of smoke but with no visible soiling, should hung in a well ventilated area away from clean PPE e.g. an outdoor covered area, or well-ventilated outhouse.
- Following fire incidents, cleaned PPE ensembles should be hung on racks to reduce drying times and to allow for continued gassing-off. Fans may facilitate this process.

Gloves and respiratory protection is recommended during decontamination of soiled PPE/clothing.



On-Site and Professional PPE Cleaning

It is important to protect skin and airways when cleaning soiled PPE/equipment.

This requires appropriate respiratory protection (e.g. dust masks) and gloves.

Wearers may be required to undertake the routine cleaning (general brush, rinse or dry) of their issued firefighters' PPE. Where possible, and where contamination type and levels allow, routine cleaning should be undertaken or begin at the emergency scene, as specified in BS 8617 (British Standards Institution, 2019). Where this is not possible, routine cleaning should be undertaken immediately in an appropriately designated area on return to the station. It is recommended that more advanced cleaning is carried out by an authorised FRS laundry services provider.

- Following fire incidents, PPE which is visibly and heavily soiled with fire debris, or has a strong smell of smoke, should be placed for collection by the professional laundry service. This PPE should be stored outside wherever possible, or at the very least in a well-ventilated area well away from workplaces or recreational areas. Outdoor, lockable "grit bins" are ideal for this purpose (Figure 27).



Figure 27: PPE awaiting collection by professional laundry services should be stored outdoors or in a well-ventilated area, e.g. a lockable grit bin.

- A log book should be kept by the individual, Service, and/or laundering provider which detail the number of professional washes the PPE has undergone, as well as any repairs and reapplication of treatments.

Improper cleaning or laundering can destroy clothing or worsen its protective performance.

Studies show that the tear resistance and seam strength decrease with application of laundering and that decontamination efficiency markedly varies.

(House & Squire, 2004; Keir et al., 2020; Mayer et al., 2019; Stull et al., 1996)

Gloves

- Soiled gloves should be sent for professional cleaning by the service provider along with tunics and leggings. Where Services have gloves that cannot be thoroughly cleaned, they should consider replacing them with gloves that can be cleaned.
- Gloves that are free of soiling or the smell of smoke may be stored in a designated kit bag away from sources of contamination.

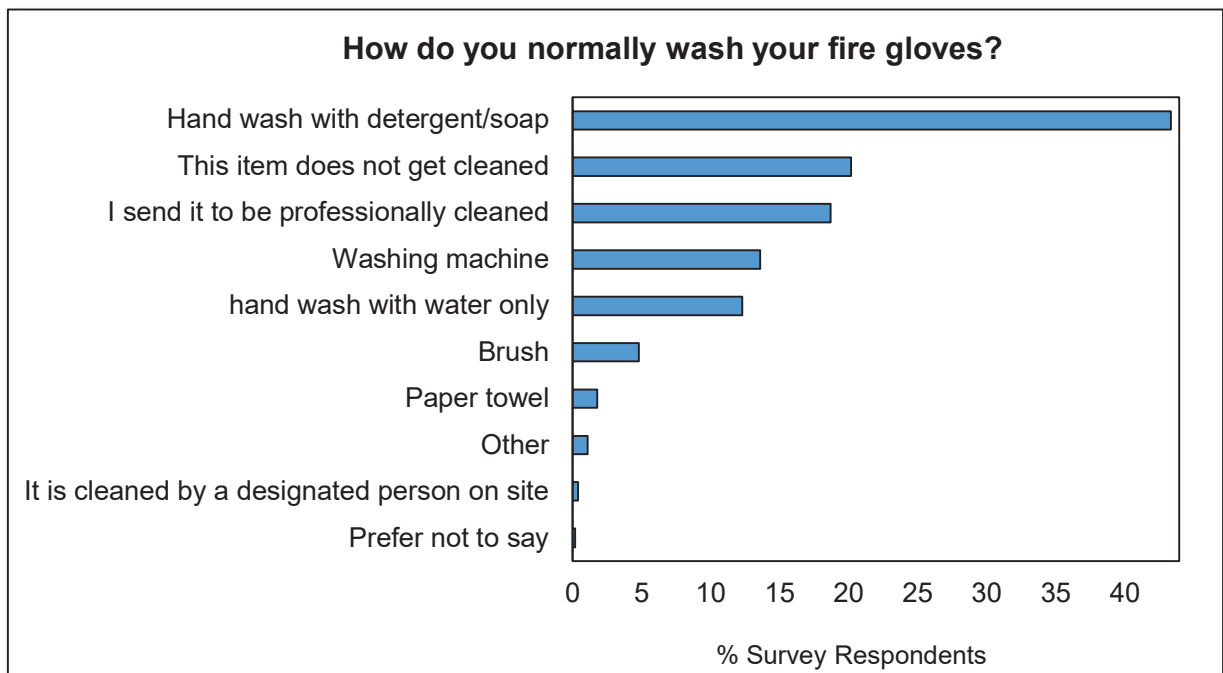


Figure 28: % of Respondents to the FBU & UCLan National Firefighter Survey who provided details on how they washed their gloves. **NOTE:** Respondents could choose more than one answer to the survey questions, thus totals will exceed 100%.

- Gloves should **not** be stored inside helmets, boots, pockets or other enclosed parts of PPE. They should be clipped onto the outside of tunics or trousers, where clips or velcro attachments exist (Figure 29). Alternatively, in-use gloves should be stored in a well ventilated space. Designated shelving, hooks or clips in the PPE storage area specifically for gloves is also appropriate (provided both gloves and storage areas are cleaned on a regular basis).



Figure 29: Gloves should be stored in a well-ventilated area, and **not** in any enclosed areas of PPE. Instead, gloves should be stored on external clips of tunics or on designated shelving/hooks.

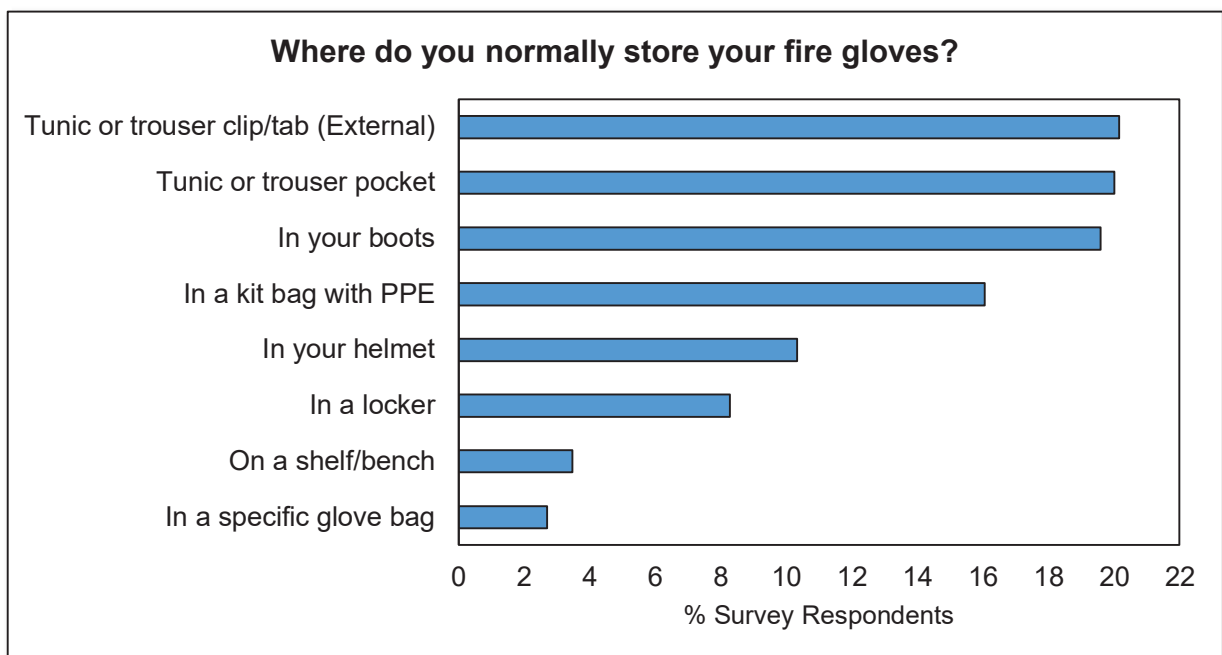


Figure 30: % of Respondents to the FBU & UCLan National Firefighter Survey who indicated where they stored their fire gloves. Storing fire gloves in enclosed areas of PPE appears relatively prevalent in common practice. **NOTE:** Respondents could choose more than one storage location in answer to the survey question, thus totals will exceed 100%.

Fire Hood

- Fire Hoods should not be dried without first washing them.
- Contaminated fire hoods should not be stored with any other clothing.
- Fire hoods **should not be taken home** and should **not be washed at home** as they will cross-contaminate other clothing.

NOTE: A second PPE set, particularly a second fire hood, is important for ensuring that firefighters do not have to wear contaminated clothing after firefighting. A second set of PPE provides firefighters with clean PPE to wear while the contaminated set is still being washed and dried or sent for professional cleaning.

Breathing Apparatus

Whether or not a firefighter will attend post-fire incidents without BA has been cross tabulated, from the national survey, with their role, and with training. Those who reported attending fewer than 1-2 fires per month have been excluded from the analysis. From the bar graph, it can be seen that as the seniority of role increases, the likelihood of attending post-fire incidents without BA decreases. Additionally, whole-time firefighters report being significantly more likely to attend post-fire without BA than RDS firefighters. There is no significant difference in attending post-fire without BA between men and women, or based on ethnicity.

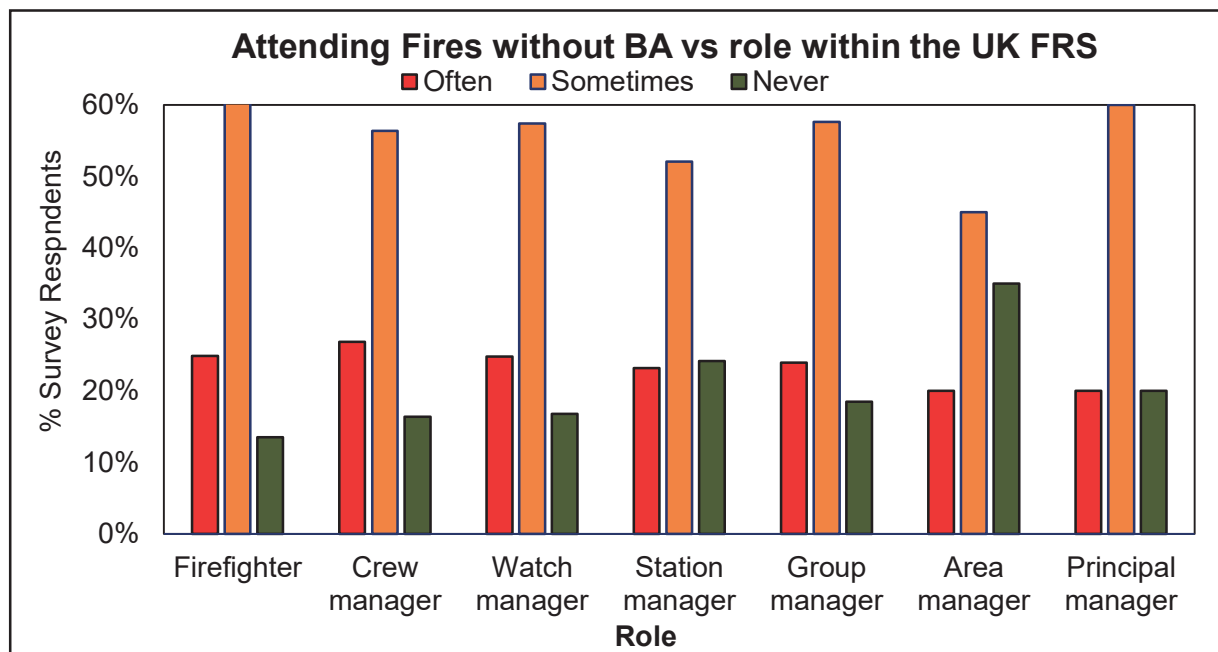
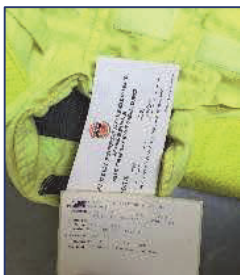


Figure 31: % of Respondents to the FBU & UCLan National Firefighter Survey on attending fires without BA

- An area of the station should be designated for the cleaning of BA sets.
- BA sets and facemasks should be cleaned according to the manufacturer's instructions with an appropriate cleaning agent or soap and water, **after every use** at a fire incident. Appropriate PPE should be worn when cleaning BA sets.
- BA sets prepped for use on call-outs should not have a noticeable smell, or visible soiling.



Figure 32: BA mask filters after and before the cleaning



PPE Records

As a minimum, the following records should be kept for each item of firefighters' PPE:

- person(s) to whom the item has been issued
- date and condition when issued
- manufacturer and model name or design
- manufacturer's identification number, lot number, or serial number
- month and year of manufacture
- date(s) and findings of advanced inspection(s)
- date of specialist/advanced cleaning
- date(s) of repair(s), who performed the repair(s), brief description of repair(s) and batch number of repair materials

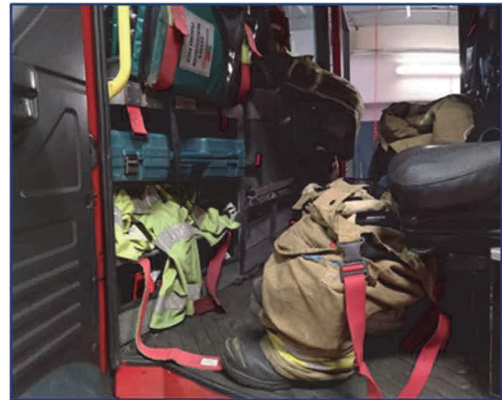
NOTE: *It might be appropriate to include a picture of the repair*

- date of PPE retirement
- date and method of disposal of PPE



Appliances and Appliance Bays: Contamination Control

- Disposable gloves should be used whenever handling soiled equipment.
- Any vehicle driven through a contaminated area must be washed down, including the undercarriage, chassis, and cab. Ideally, this must be done in fresh air.
- Soiled hoses (having large quantities of the fire incident debris, dust, soot, particles and contaminants which may become partially airborne) should be soaked in water until washed and cleaned thoroughly. Gloves and respiratory protection, and possibly fire full gear should be worn to prevent any skin contact with contaminants.
- Appliance cab air/pollen filters must be inspected regularly and replaced if any visible contaminant is present.
- Ideally, no potentially contaminated equipment should be stored or transported in the appliance cab.
- No equipment with a designated use for interior firefighting should be housed, bracketed, stored or otherwise kept in the passenger compartment of any response vehicle.



Lockers and equipment e.g. hoses, hand tools, thermal imaging cameras, power tools, piercing nozzles, branch pipes, crowbars, Halligan tools, lines, spades etc. should be cleaned at the incident before further washing/wiping down with disposable cloths, wipes or water spray as appropriate back at the workplace.

- All equipment, including SCBA sets and cylinders, tools, radio straps, and appliance cab etc. should be thoroughly cleaned using wipes, water or any available cleaner, according to the manufacturer's recommendations. Soft bristle scrub brushes can be also used to assist decontamination.



- Appliance bay doors should be opened **prior** to starting the engine, or an exhaust system should be used to facilitate the removal of deisel exhaust fumes.
- The appliance bay should be well ventilated, ideally with bay doors kept open, especially on return from a fire incident. Appliances should also be well ventilated on return from a fire incident e.g. by leaving windows and doors open.

To reduce secondary exposures, appliance cabs and tools should be cleaned and decontaminated on a regular basis, especially after incidents where exposure to any combustion products occurred.



BA WORKSHOPS: CONTAMINATION CONTROL

- BA workshops should be well ventilated with open windows or doors, or have an air filtration system fitted.
- If particulate matter is frequently generated intentionally for training purposes, then monitoring should be in place to assess exposure of BA technicians to those contaminants.
- Surfaces and workspaces should be kept clean from dust and soot, by cleaning with warm soapy water.
- BA sets should be clean of visible soiling and the smell of smoke **before** they are returned to BA workshops.
- Where BA sets cannot be cleaned before being sent to workshops they should be sent in an airtight container (Figure 33). On receipt at workshops, but before assessment by BA workshop personnel, BA sets should be allowed to ventilate outdoors, or in a well-ventilated space away from personnel working spaces, until all smell of smoke has completely dissipated.
- If BA sets have been returned to BA workshops in a soiled condition they should be washed according to manufacturer instructions at the workshop, before maintenance work is carried out.
- Disposable gloves should be used when handling BA sets which are visibly soiled or have a smell of smoke.
- Respiratory protection, such as particulate masks, should be available if there are heavily soiled BA sets, and there is the potential for debris, such as soot, to become airborne during the maintenance work.
- After handling soiled sets, personnel should wash their hands and any other exposed area of skin using soap and water.
- BA workshops should consider the use of Contamination Zones (see “Contamination Zones” Section), whereby contamination is managed through restricting the areas within a location in which potentially contaminated items can travel, be stored/worn and/or be decontaminated.

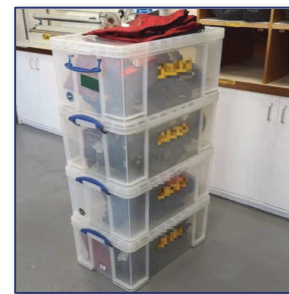


Figure 33: BA airtight container



TRAINING CENTRES: CONTAMINATION CONTROL

- Live fire training should only involve the burning of clean plywood or untreated and fire-retardant free OSB.
- Training centres should designate Contamination Zones according to the level of risk from contamination.
- Where there is the potential for fire effluent to be blown into office spaces, or other “clean” areas, there should be adequate ventilation or air filtration measures to keep exposure as low as reasonably possible as well as routine testing to monitor contamination levels.
- Where it is not possible to stop all fire effluent from being blown into the building due to the design of the building, all the doors and windows should be shut during training, and the workplace should be routinely monitored for at least VOCs and particulates.
- There should be provisions at each training facility to wash base layers that have been worn to a fire incident.





Instructors and Trainees

- Training instructors and trainees should wear adequate respiratory protection whenever there is the potential for exposure to effluents. If the instructor needs to brief students about the behaviour of the burn, this must be done in fresh, clean air.
- Training instructors and trainees should stand upwind of the burn if they are not wearing respiratory protection.
- Time and facilities must be provided and built into training programmes for training instructors and trainees to have a shower as soon as possible after exposure to fire effluents or debris. This may be immediately after a burn, or at the end of the training session.
- Skin and airways must be protected during cleaning of soiled PPE and equipment, e.g. by using dust masks and disposable gloves.
- Hands and face and any other exposed skin should also be cleaned after carrying out any cleaning of soiled PPE or equipment.
- Adequate respiratory protection and clothing must be provided to any personnel who are involved with cleaning buildings or containers where burns take place.



PPE and equipment

Soiled clothing, including undergarments with a smell of smoke, must not be taken home until they have been washed.

- Training instructors should have an adequate number of changes of PPE such that they do not wear soiled garments. This should include tunics, leggings, fire hoods and gloves.
- Lightly contaminated PPE, such as that with a slight smell of smoke but no visible soiling, should be allowed to hang in a well ventilated area, such as an outdoor covered area, or well-ventilated outhouse.
- PPE which is visibly soiled with fire debris, or has a strong smell of smoke, should be placed for collection by a professional laundry service.
- Soiled PPE which is awaiting collection by a laundry service should be stored outside wherever possible, or at the very least in a well-ventilated area which is well away from workplaces or recreational areas. Outdoor, lockable “grit bins” are ideal for this purpose.
- BA sets and face masks should be cleaned thoroughly, according to the manufacturers instructions, every time they are used (Figure 34).

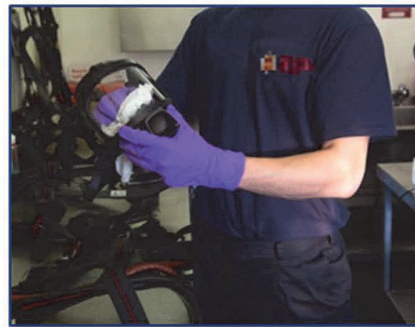


Figure 34: BA sets and masks should be cleaned after each wear according to the manufacturer's instructions

Training facilities use many more respiratory protection devices compared to FRSs. To facilitate quick and thorough decontamination of compressed air breathing apparatus and other PPE thoroughly, it may be more efficient to use a purpose-built machines (see “Respiratory Protection” section).



ADDITIONAL CONSIDERATIONS FOR FRS PERSONNEL RESPONDING IN THEIR PERSONAL OR FRS PROVIDED VEHICLES

Fire investigators must never be permitted to enter post fire incidents without the proper PPE and SCBA.

- At all incidents post fire, fire investigators must wear appropriate PPE and RPE.
- Where fire gloves are not required, heavy gauge nitrile gloves should be worn to reduce dermal contact with contaminants.
- Disposable paper suits may reduce the amount of soiling on PPE or clothing, reducing laundering requirements.
- Disposable overshoes may reduce the amount of soiling on boots, reducing the possibility of contamination being transported into the car, workplace or home.
- Clothing or PPE becoming soiled, or having a smell of smoke, should be removed at the incident and changed for a clean set of clothes.
- Soiled clothing or PPE must not be transported in cars (or personally owned vehicles), it should be bagged or stored in an airtight container thus keeping the PPE gassing-off away from passengers (Figure 35).
- Fire investigators should wash their hands and any other exposed area of skin as soon as possible after contact with fire debris. There should be washing facilities on site. Wipes should be provided as a minimum.
- After exposure to fire debris or fire effluent, fire investigators must return to a FRS venue with showering facilities to have a shower as soon as is reasonably possible (this will allow them to remove contamination as well as stop spreading toxic chemicals in their vehicle and home, potentially exposing family members).



Figure 35: PPE with visible soiling, or the smell of smoke, should be bagged or stored in an airtight container.

- Soiled clothing or PPE should be sent to for professional cleaning by the Service provider. Soiled clothing, including undergarments with a smell of smoke, should not be taken home until they have been washed.

Fire investigators and RDS firefighters must be able to shower prior to leaving the workplace so that they do not carry contaminants home.



HEALTH SCREENING

Many firefighters begin work at a young age and typically remain in the profession their entire working lives, until retirement. This means that there is plenty of opportunity and time for them to be exposed to large quantities of harmful and toxic substances.

- Health screening should be provided to any staff who have or have previously had regular exposure to fire effluent.
- Getting an annual health screening and evaluation is essential, as early detection is the key to survival.
- Regular lung function screening should be provided for personnel who are regularly exposed to smoke, such as training instructors or personnel working within live fire training facilities.
- Training on the potential long-term health effects of exposure to fire debris and fire effluent should also be provided to all personnel on a regular basis.
- It is important that firefighters get an annual physical and make sure their healthcare provider is informed of their increased cancer risks.

EARLY DETECTION SAVES LIVES

“Screening increases the chances of detecting certain cancers early, when they are most likely to be curable”

(World Health Organization, 2020).

Keeping Records

Documentation of exposures at all incidents has become a priority in the fight against occupational cancer. Tracking exposures can help firefighters better understand their risks, more effectively communicate these risks to their healthcare provider.

Therefore, it is crucial to keep detailed records of every fire incident attended and of any other relevant exposures. Recording exposures as soon after the event as possible will help to preserve details of the exposure which might otherwise fade with memory. It may also be beneficial to share such records with the occupational health department, such that a proper health screening and check-up can be organised for personnel on an annual basis.

Documentation should cover only the role undertaken during the incident. Incident Commanders and other fire personnel will be exposed to differing levels of fire effluent throughout an incident. Key points which should be recorded are listed for consideration below, along with an example of a template which might be used to record this information:

- **Annual health screening and check-up information;** to ensure that a firefighter is in good health and able to perform the essential functions of the job. This information also provides a baseline for correlating any health diagnoses with exposure history, and allows early identification of any potential health issues.
- **Role and incident-specific exposures;** It is vital that firefighters record details about a fire incident, but also all role-specific actions at the incident which might influence the type and level of exposure. This should include:
 - date, type and length of the fire incident,
 - incident number of the incident recorded by FRS,
 - if possible, types of products involved in the fire,
 - actions undertaken at the incident (including approximate duration/s) during the fire and during turning over,
 - the type and length of potential exposure (dermal, inhalation etc.),
 - evidence of contamination (hands, face, neck etc.),
 - actions taken for personal decontamination and level of decontamination achieved.

- **PPE maintenance, training and/or fitting information;** e.g. use of correct donning and doffing procedures, proper care for PPE etc. This information will ensure that a firefighter is well-equipped with properly fitted PPE and that the PPE is in good condition as per the manufacturer's specifications. It is important to record the type, age and number of on-site and/or professional washes for all PPE.
- **Health symptoms;** if any health symptoms arise at any point (cough, dry mouth, loss of sense of smell, soot in the nose, etc.), symptoms and length of time the symptoms persisted must also be recorded, and checked by a health care provider.

Documentation can be seen as a chore, but it should be valued as a tool to better the workplace and working conditions.

Example: A USA Occupational Exposure Tracking Form

A UK version is currently being developed.

Occupational Exposure Tracking Form	
Incident Information	
Date: _____	Time: _____ Incident #: _____
Location: _____	
Incident Type (Description of this incident)	
<input type="checkbox"/> Structure Fire	<input type="checkbox"/> Heavy Rescue <input type="checkbox"/> Standby
<input type="checkbox"/> Car Fire	<input type="checkbox"/> EMS Incident
<input type="checkbox"/> Hazmat	<input type="checkbox"/> Investigation
<input type="checkbox"/> Other _____	
Personal Protection Equipment (List of PPE used during this incident)	
<input type="checkbox"/> Helmet	<input type="checkbox"/> SCBA <input type="checkbox"/> Suppression Boots <input type="checkbox"/> Station Uniform
<input type="checkbox"/> Suppression/Work Gloves	<input type="checkbox"/> Station Boots <input type="checkbox"/> Fire Hood <input type="checkbox"/> Safety Glasses
<input type="checkbox"/> Other _____	
Operational Role (List of roles assumed during this incident)	
<input type="checkbox"/> Interior Fire Operations	<input type="checkbox"/> Interior Investigations/Monitoring
<input type="checkbox"/> Exterior Fire Operations	<input type="checkbox"/> Driver/Pumper Operations
<input type="checkbox"/> Overhaul	<input type="checkbox"/> Standby
<input type="checkbox"/> Other _____	
Possible Exposures (List of potential hazardous materials encountered during this incident)	
<input type="checkbox"/> Products of Combustion	<input type="checkbox"/> Hazardous Materials <input type="checkbox"/> Airborne Dust <input type="checkbox"/> Construction Debris <input type="checkbox"/> Diesel Exhaust
<input type="checkbox"/> Other _____	
Signs/Symptoms (List of signs or symptoms experienced during or after this incident)	
<input type="checkbox"/> Cough	<input type="checkbox"/> Head Ache <input type="checkbox"/> Nausea
<input type="checkbox"/> Wheeze	<input type="checkbox"/> Chest Pain <input type="checkbox"/> Vomiting
<input type="checkbox"/> Sore Throat	<input type="checkbox"/> Dizziness <input type="checkbox"/> None
Other _____	
Notes: _____	



PREGNANCY, MATERNITY AND FERTILITY

The job of firefighting presents many potential hazards to healthy reproduction. It poses physical hazards such as drastic temperature variations, extreme and unpredictable physical exertions and demands, psychological stress etc. Firefighters may also be exposed to biological or radiation hazards as well as many toxic and persistent contaminants released from fires (McDiarmid et al., 1991).

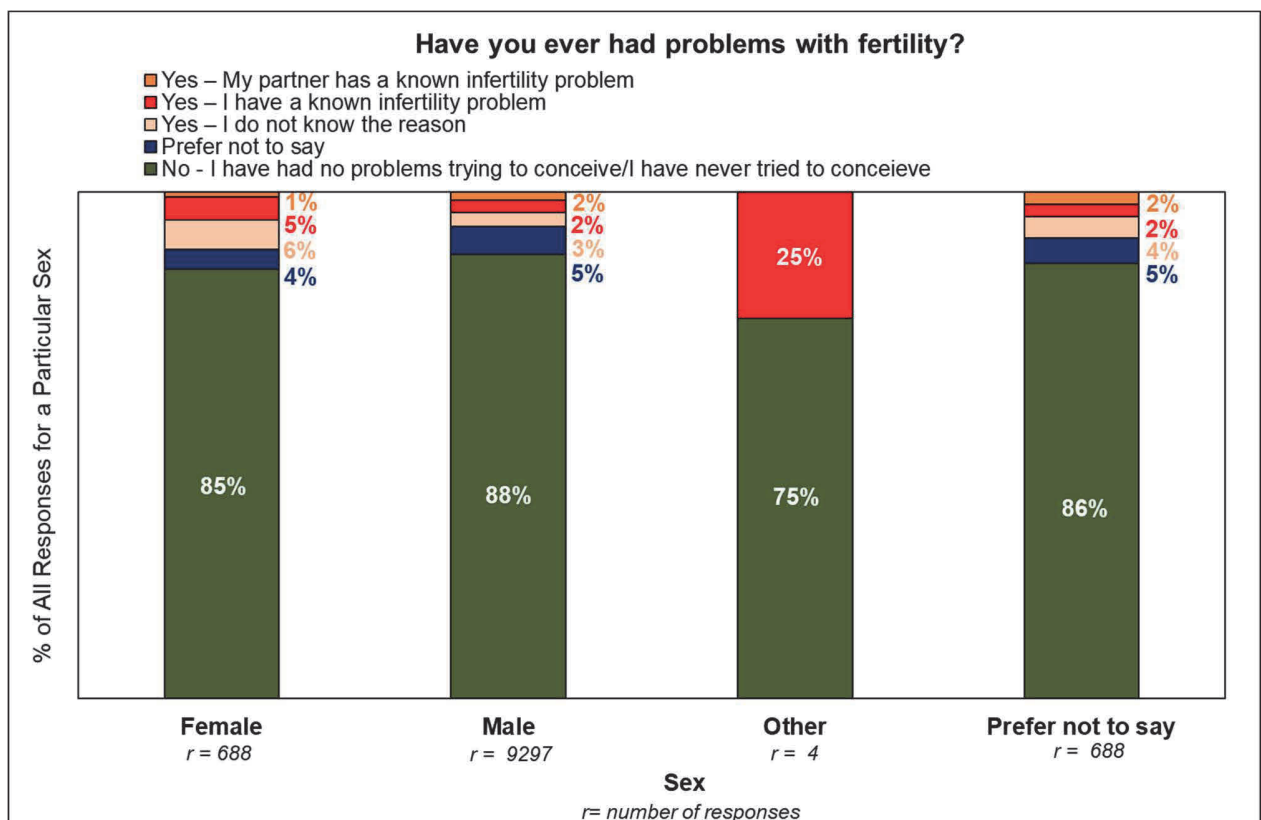


Figure 36: % of Respondents to the FBU & UCLan National Firefighter survey who indicated whether they had suffered problems with fertility, grouped by sex.

Results from one study showed that nearly a quarter (25%) of studied US female firefighters' first pregnancies ended in miscarriage (compared to 10% in the general US population). Rates of pre-term deliveries were also reported to be high among this population.

(Jahnke et al., 2018)

Exposure to contaminants during pregnancy can be harmful not only to mothers, but also to the developing foetus. The foetus is more sensitive to much lower doses of contaminants than an adult (Scheuplein et al., 2002). Contaminants which are inhaled, ingested or dermally absorbed by the mother can enter the blood stream and expose the developing foetus through the umbilical cord (Mitro et al., 2015). There may also be more indirect harmful effects to the foetus, for example by disrupting hormones in the mother's body which are important for maintaining a healthy fetal environment (Mitro et al., 2015).

Real risks to foetuses from hazardous exposure occurs mostly in the first trimester. For example, high heat exposure leads to elevated core body temperature which is known to be a serious risk factor for neural tube disorders in foetuses, such as spina bifida.

It is therefore important that every action is taken to protect pregnant firefighters from exposure to contaminants and physical stresses. The following must be considered for protecting the health of pregnant firefighters and their unborn children:

- Fully risk assessed procedures should be devised for the protection of pregnant firefighters. All relevant staff should be fully aware of, and trained in, implementing these procedures. These should cover: duty re-assignment; adverse consequences to the pregnant firefighter's safety; maternity leave; return to work.
- To capture all adjustments and considerations that may be required during the changes that take place during pregnancy it is recommended that risk assessments are revised on a regular basis and/or when they are believed to no longer be suitable and sufficient.
- Pregnant firefighters should inform their FRS (line manager, human resources or occupational health - as preferred) as soon as pregnancy is suspected – so that protective measures can be put into place as early as possible (FBU, 2008; National Joint Council for Local Authority Fire and Rescue Services, 2009).

- Pregnant firefighters must be reassigned to non-operational duties away from exposure to contaminants and the hazards of physical stress and exertion, noise or heat (e.g. long hours without sleep, driving engines under emergency conditions, etc.) (FBU, 2008).

Every FRS needs to be aware of risks related to pregnancy and firefighting activities.

Firefighters who are Nursing Mothers

Even after pregnancy, babies can continue to be at risk of exposure to the contaminants that their mothers are exposed to through the ingestion of breast milk. Contaminants that have built up in the mothers' tissues over months or years can be passed directly onto infants in concentrations that are much higher than any single exposure event their mother may have experienced (Nickerson, 2006). In addition, those contaminants can be eliminated from the body much faster when breast feeding (Nickerson, 2006). This emphasizes the importance of minimising exposure to such contaminants at all times, even before pregnancy and breast feeding.

The same precautions which are applied to pregnant firefighters are applied to breastfeeding firefighters (Council of the European Communities, 1992).

- On return to work after maternity leave, firefighters have the right to resume the position they held under their original contract of employment and on terms and conditions not less favourable than those that would have been applicable if they had not been absent.
- Breast feeding firefighters must be reassigned to non-operational duties in order to minimise exposure to harmful contaminants.
- To ensure avoidable exposure to contaminants is minimised the FRS should consider any requests from employees to work different/part time hours (flexible working) on their return from maternity leave.
- A safe and private space within a "clean" zone of the station or work environment should be provided for breastfeeding firefighters to pump breast milk if required.

- Facilities to store expressed milk should be provided in “clean” zones of the station or work environment as requested. The FRS should provide access to a refrigerated storage facility and reasonable time for expressing breast milk.

Contaminants can be passed to babies through their mothers' breast milk.



TRAINING AND AWARENESS

In order to provide positive motivation for change, it is necessary to communicate the risks posed by poor or non-existent contamination control routines. When firefighters gain knowledge and awareness of contaminants and their effects on health, it becomes much easier to introduce improvements and implement changes.

The Badge of Honour

The "**Badge of Honour**" attitude refers to firefighters being proud of having soiled PPE because it may give the impression to others that they are more qualified or hardworking. This attitude still appears to be prevalent in the UK FRS (see Figure 37). Dispelling the sentiments behind the badge of honour attitude will therefore require dedicated training for firefighters, and increased awareness among the UK FRS more broadly.

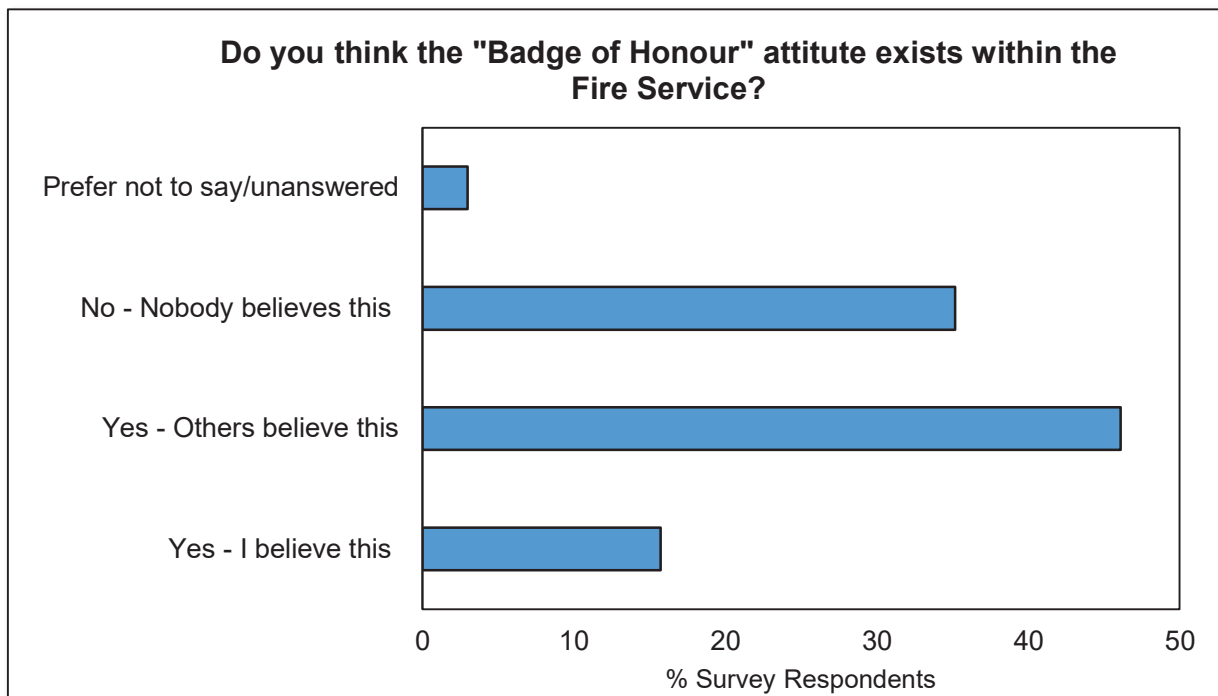


Figure 37: % of Respondents to the FBU & UCLan National Firefighter Survey who indicated whether they thought the "Badge of Honour" attitude exists within the Fire Service

Awareness

Key notes from UK FRS submitted documents:

- Training on the wearing, fitting and use of PPE appears to be fairly consistent across Services, with firefighters being trained on how the PPE can protect them in fires, and the importance of correctly fitting PPE to ensure adequate overlap and range of movement.
- There is limited documentation related to training on contaminants and their toxic effects. The most common distribution of such information is through FBU posters and circulars.
- The responses collected show that only 2 FRS provided evidence of dedicated training on the importance of keeping PPE clean and avoiding cross contamination in order to keep firefighters healthy.

When people routinely and repeatedly find themselves in similar circumstances, such as attending fire incidents, they tend to develop **habitual blindness**. Habitual blindness means that a person subject to repeated experience of the same situation or phenomenon becomes numb to it and stops reacting to, or even noticing the circumstances in question (Miller et al., 2001; Swedish Civil Contingencies Agency, 2015).

An individual with their own negative experiences of an event (e.g. resulting in illness or accident) generally assesses similar events as being much higher risk than others who have not had this negative experience. Such individuals are generally more careful. But as time passes, this caution diminishes (Weinstein, 1989). This phenomenon puts firefighters at risk of gradually resuming bad habits and routines, even after those routines may have led to illness or accidents (Reason, 1997; Swedish Civil Contingencies Agency, 2015).

“ONE FOR ALL, AND ALL FOR ONE”

Teamwork is crucial for changing behaviour.

Firefighters' behaviour is heavily influenced by the behaviour of colleagues. It is difficult for a single individual to break a harmful pattern alone. Knowledge and awareness must therefore be disseminated and accepted throughout the workplace if it is to have the intended impact.

It is well documented that risk perception differs significantly between women and men. Studies show that safety awareness is generally better among women than among men (Swedish Civil Contingencies Agency, 2015). Men have been found to struggle to immediately see the positive benefits of safety measures compared to women and have been reported to be overall less concerned about safety measures than women (particularly when assessing risks to an individual). Studies found that men tended to feel that they already had sufficient information and knowledge concerning risks and safety issues. Given the gender balance of the UK FRS, firefighters may be more likely to underestimate health risks in the work environment when compared to groups with a more even gender distribution (Gustafson, 1998; Swedish Civil Contingencies Agency, 2015).



Training

The majority of responses to the FBU & UCLan National Firefighter Survey indicated that firefighters had not received training on the potential health effects of exposure to smoke and gases, and that this majority would find this type of training useful (Figure 38). Of those that *did* receive training on the health effects of smoke and gases, the majority indicated that they found this training useful.

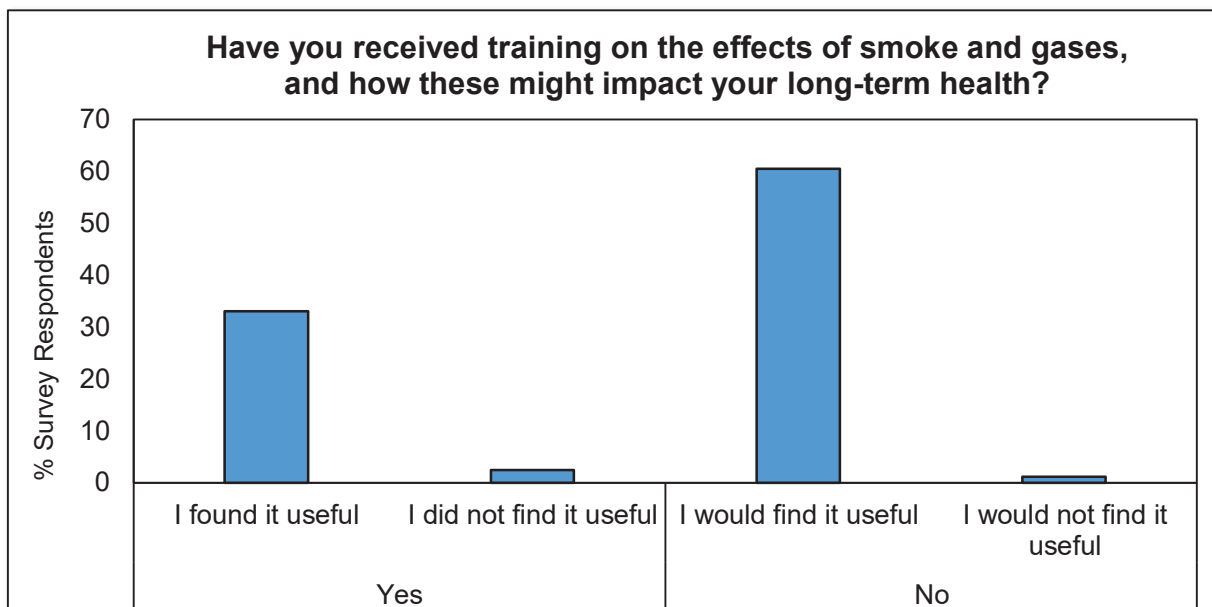


Figure 38: % of Respondents to the FBU & UCLan National Firefighter Survey indicated they would find training on the effects of smoke and gases useful.

Key considerations for implementing such training on a wider scale are listed below:

- It is essential that firefighters and maintenance personnel are trained in the selection, use, care and maintenance of all personal protective equipment.
- In line with HSE regulations on PPE at work, all wearers of respiratory protection should have up to date training on the protection and limitations of the equipment. This should be the case for all respiratory protection, whether it is full SCBA, half face respirators, particulate masks, dust masks or other equipment.
- Training should be provided to all personnel on-site, including support staff, who may be exposed to fire effluent from live fire training burns.
- In addition to training, there should also be documentation on-site, which details the risks of chronic exposure to fire effluent and debris, as well as measures to reduce the risk. This may be in the form of posters, or documentation such as this guidance.
- A list of resources should be available to personnel which provides information about minimising contamination risks, cancer in firefighters, and other health risks associated with exposure to fire effluent and debris.



TRAINING ON THE ACUTE AND CHRONIC TOXICANTS

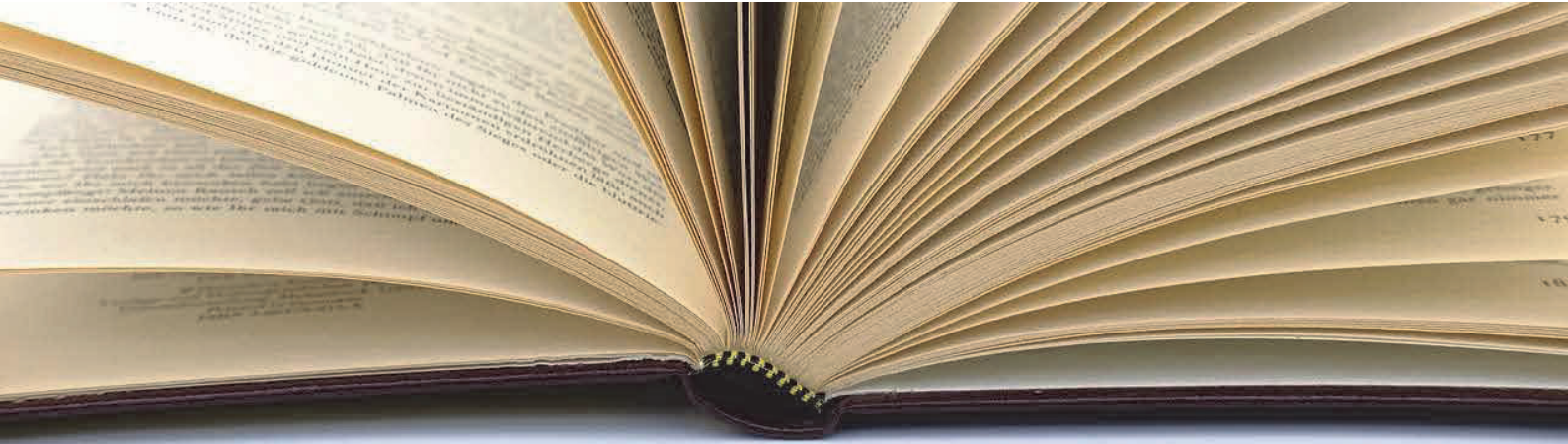
produced by fires should be provided to all fire personnel at all levels of the organisation, including training instructors, BA workshop technicians, fire investigators and other personnel who may come into regular contact with fire debris or fire effluent. This training should cover:

1. Fire effluents: their release, toxicity and hazardous effects on firefighter's health:

- Potential sources of acute and chronic toxicants.
- Relationship between fire conditions and the types and quantities of acute and chronic fire effluents released.
- Health effects which can arise from exposure to both acute and chronic toxicants.
- Exposure pathways for toxicants (inhalation, ingestion, dermal absorption).

2. The best practices and prevention methods to reduce contamination and exposure to fire toxins:

- Purpose and limitations of PPE, including the limitations of each available type of respiratory protection.
- Different pathways via which toxicants are transported from the fire ground to the workplace.
- Protocols for cleaning equipment and PPE.
- Methods for reducing personal exposure to chronic toxicants.



GLOSSARY

A

- Acute toxicity** - adverse health effects occurring within a short time period of exposure to a single dose of a chemical or as a result of multiple exposures over a short time period e.g. 24 hours.
- Adverse (health effect)** - a harmful effect on health.
- Aerosol** - a colloidal suspension of liquid or solid particles dispersed in gas having a negligible falling velocity (generally considered to be less than 0.25 m/s).
- Alveolar** - concerning the alveoli of the lungs. Alveoli are structures within the lungs resembling microscopic “air sacs”, which facilitate exchange of oxygen and carbon dioxide between the lungs and blood.
- Appliance** - The fire fighting vehicle utilised by the fire station for the purpose of answering emergency ‘call outs’.
- Appliance bay** - The location within the fire station where the appliances are stationary and awaiting an emergency call out.

Asphyxiation - deprivation of oxygen which can result in unconsciousness, suffocation and ultimately death.

B

BA servicing area - the area dedicated to the servicing of breathing apparatus.

Base layer - the layer of clothing worn directly beneath PPE, for example, t-shirt and trousers.

Bioaccumulate - the ability of a chemical to become concentrated in the tissues of living organisms.

Biocide - a chemical substance capable of destroying harmful organisms (e.g. some bacteria and other microorganisms).

Breathing Apparatus (BA) - self-contained, positive pressure, respiratory protective equipment.

C

Cancer - Collective name for illnesses involving uncontrolled cell growth that destroy cell tissue.

Carcinogen - A chemical or physical agent capable of causing cancer.

Cardio-toxic - Specifically toxic to the heart and circulatory system.

Chronic - Occurring for a prolonged period.

Chronic toxicity - Adverse health effects in a living organism resulting from repeated exposures to a chemical for a significant part of the organism's lifespan.

- Cirrhosis** - Excessive scarring of the liver which is caused when the liver tries to repair itself after damage (e.g. due to disease or excessive alcohol consumption).
- Cilia** - microscopic, hair-like structures on the surface of cells which help to move/transport substances through the body.
- Circadian Rhythms** - Daily cycles of behavioural and physical biological changes that occur within the body. The sleep-wake cycle is an important example of a circadian rhythm and is largely affected by changes in daylight.
- Cleaning** - process by which an item of personal protective equipment (PPE) is made serviceable and/or hygienically wearable again by removing any dirt or contamination.
- Combustion gases, Combustion products** - Energy-rich residues from incomplete combustion, in gas and particle form, which are expelled from fire.
- Concentrated** - increase the concentration of a substance i.e. increase the amount of a contaminant over a given area or volume.
- Contamination** - occurs when a substance adheres or is deposited on people, equipment or the environment, thereby, creating a risk of exposure and possible injury or harm.
NOTE: Contamination does not automatically lead to exposure but may do.
- Compressed air** - Air which has been compressed under pressure for transportation or use
- Corrosive** - A substance that chemically attacks a material with which it has contact.
- Cross contamination** - occurs when a person or object that is already contaminated makes contact with a person or object that is not contaminated.

D

- Debris** - solid remains of a material following combustion. For example, char or partly burned material
- Decomposition** - chemical reaction whereby a substance breaks down into its constituent elements. In the case of acetylene this means carbon and hydrogen. This reaction gives out a great deal of heat.
- Decontamination** - decontamination is the physical and/or chemical process of reducing contamination to minimise the risk of further harm occurring and to minimise the risk of cross contamination to a level as low as reasonably practicable.
- Decontamination Area** - the area containing the FRS (and possibly other emergency services') decontamination staff, equipment and structures. It is a suitable area initially established outside the inner cordon, at first uncontaminated by the initial release, which becomes contaminated by the managed and controlled movement of people who require decontamination. Prior to decontamination commencing, the inner cordon will be adjusted to encompass the decontamination area.
- Degradation** - the continuing action of chemical attack to which chemical protective clothing may be subject to in use or during storage.
- Dermal** - of, or related to, the skin.
- Dose** - the amount of a substance which an individual is exposed to.
- Dust** - solid particles generated by mechanical action, present as airborne contaminant (less than 0.076 mm in size).

E

- Effluent** - gases, aerosols and airborne particulates produced from a fire.

- Ensemble** - A firefighter's full set of personal protective clothing, which when worn correctly, minimises the thermal effects on their body.
- Epithelial (cells or tissues)** - Cells which form a thin layer of tissue on the outer layer of the body's surface (e.g. skin epithelial cells), or which line cavities within the body (e.g. lungs, and organs of the digestive system).
- Exposure** - exposure occurs when a harmful substance enters the body through a route, for example, inhalation, ingestion, absorption or injection.

F

- Fire kit** - The firefighter's personal protective clothing which, when worn correctly, minimises the thermal effects on their body.
- Foetus** - The unborn child developing in the mother's womb.
- Fumes** - Airborne solid particles (usually less than 0.0001mm) that have condensed from the vapour state.
- FRS** - Fire and Rescue Service – provided by a fire authority under the *Fire and Rescue Services Act 2004*.

G

- Gas** - Gas is one of three classical states of matter. Near absolute zero, a substance exists as a solid. As heat is added to this substance it melts into a liquid at its melting point, boils into a gas at its boiling point. What distinguishes a gas from a liquid or solid is the vast separation of the individual gas particles.
- Genotoxic** - A chemical or agent which is capable of damaging genetic material within cells, which can lead to mutations. These mutations can result in adverse health effects, such as the development of cancer.

H

- Hazard** - A hazard is anything that may cause harm.
- Hydrocarbons** - Compounds which are composed of atoms of hydrogen and carbon only.
- Hypersensitivity** - an adverse immune response e.g. an allergic reaction, which can be caused by exposure to a chemical substance.

I

- Inflammatory** - causes inflammation type immune response within the body.
- Ingestion** - Taking food, drink or other substances into the body by swallowing it.
- Inhalation** - Drawing air, or other substances, into the airways and lungs.
- Incomplete combustion** - Combustion without sufficient oxygen input, which means that residual products from the fuel remain or spread. This is always applicable to some extent in accidental fires.
- Inspired** - to take air in (to the lungs) i.e. to breathe in.
- Irritant** - substances which can cause inflammatory immune responses to occur in the body.

K

- Kit room** - The area within the station used for the storage of in-use Personal Protective Equipment. May also be referred to as the PPE room, Muster Bay or Gear Room.

L

- Laundering** - Process intended to remove soiling and/or stains by treatment (washing) with an aqueous detergent solution and normally including rinsing, extracting and drying.

Latent Period - The period of time between infection, or exposure to a disease-causing agent, and the onset of symptoms e.g. the period of time between exposure to contaminants and the appearance of cancer.

Lesion - An area within tissues, organs etc. which has suffered damage or abnormal changes e.g. caused through injury or disease.

M

Macrophage - A type of cell responsible for destroying foreign pathogens (e.g. bacteria and viruses) and the body's own damaged/dying cells.

Melatonin - A hormone produced by the body which helps to regulate sleep cycles.

Mutagenic - Chemical or physical agent that can cause a change in the genetic material of a living cell.

N

Neural Tube Disorders - Birth defects of the brain, spine or spinal cord.

Neurological Disorders - Disorders which affect the brain, spine, spinal cord and nerves.

P

PAH - polycyclic aromatic hydrocarbons.

Particle - a small portion of matter, such as soot, and small parts of residual substances from combustion.

Permeation - the process by which fire effluent chemical moves through a protective clothing material on a molecular level.

- Persistence** - Persistence of chemicals indicates that they are stable and long-lived in the environment, resisting degradation, e.g. lead, cadmium, mercury and many manmade organics.
- Personal protective equipment (PPE)** - Any clothing or equipment intended to provide protection to the user. This may be from heat, toxicants, or other hazards. In this document it should be taken to mean tunics, leggings, fire hoods, gloves, helmets and boots, unless otherwise stated.
- Practicable** - Capable of being done in the light of current knowledge and resources.
- Pulmonary oedema** - Production of watery fluid in the lungs.

R

- Renal Dysfunction** - Failure of the kidneys to perform their function within the body.
- Residue** - condensed effluent. For example, the soot left on surfaces following exposure to smoke.
- Respirable dust** - that fraction of total inhalable dust which penetrates to the gas exchange region of the lung.
- Respiratory sensitiser** - a substance that may cause sensitisation in the respiratory system on inhalation, causing, for example, asthma, rhinitis etc.
- Risk** - risk is the probability that somebody could be harmed by a hazard or hazards, together with an indication of how serious the harm could be.

Risk Assessment - a risk assessment is simply a careful examination of what, could cause harm to people, in order to weigh up whether enough precautions have been taken or more should be done to prevent harm. The law does not expect the elimination of all risk, but the protection of people as far as is 'reasonably practicable'.

RPE - respiratory protective equipment.

S

Safety - A state where exposure to hazards has been controlled to an acceptable level.

Sensitiser - A substance that can causes allergic type hypersensitivity reactions within the body.

Smoke - Particulate matter, usually less than 0.0005 mm in diameter, in air resulting usually from combustion, including liquids, gases, vapours and solids.

Solid - Solid is one of the classical states of matter. It is characterised by structural rigidity and resistance to changes of shape or volume. Unlike a liquid, a solid object does not flow to take on the shape of its container, nor does it expand to fill the entire volume available to it like a gas does.

Standard Mortality Rate - The observed rate of mortality (death) within a given population standardised against the expected rate of mortality for that population.

Support staff - Refers to staff that have a support role in relation to the Service and not having a fire fighting role to play.

Surface contamination - Hazardous materials adhering to a vertical surface or resting on a horizontal surface.

T

- Teratogen** - chemical or physical agent that can cause defects in a developing embryo or foetus when the pregnant female is exposed to the harmful agent.
- Thermoregulatory Process** - Biological processes within the body which control and maintain the body's core temperature.
- Toxicity** - the degree to which something is toxic.
- Toxicant** - a substance that has the potential to have a detrimental effect on health.
- Toxin** - poisons produced inside the body. May be produced by the body as a result of exposure to a toxicant.

V

- Vapour** - vapour refers to a gas phase at a temperature where the same substance can also exist in the liquid or solid state, below the critical temperature of the substance. If the vapour is in contact with a liquid or solid phase, the two phases will be in a state of equilibrium.
- Vascular Disease** - Disease which affect the blood vessels (veins and arteries).
- Ventilated** - allowing the free movement of air to circulate within a room, building, etc.
- VOC** - volatile organic compounds. Compounds that cause damage to organs and the nervous system.

W

- Washing** - to remove contamination from clothing by or as by the action of water, detergent and mechanics

- Workshop** - an area of benching and lockable storage, may be within the appliance bay or in a dedicated building. Dedicated to the upkeep and maintenance of appliances.

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APPENDIX

Decontamination procedures should aim to:

- Minimise the risk of people being exposed to contaminants.
- Enable responders to remove contaminated clothing, personal protective equipment and respiratory protective equipment without being exposed to hazardous materials.
- Stop hazardous materials being spread beyond the decontamination area.

Decontamination Methods

Although breaches and/or failures of PPE can happen, poor decontamination is the most common cause of exposure to harmful fire effluents.

There are several specific methods which can be used for decontamination. These methods can be broadly divided into two basic categories: “**dry**” (or “**physical**”) **decontamination methods** and “**wet**” (or “**chemical**”) **decontamination methods**. Each of these types of methods is discussed in further detail below.



Dry (physical) decontamination

These methods involve physically removing the contaminant from the contaminated person or object. These methods are often easy to perform and work by reducing the amount (dose) of a contaminant, thus reducing its potential to cause harmful health effects. However, the contaminants generally remain chemically unchanged (National Operational Guidance (NFCC), 2020). Common examples of dry decontamination practices include:

- **Absorption**; this involves soaking up liquid contaminants/hazardous materials to prevent the liquid spreading to (and contaminating) a larger area, e.g. wiping off PPE and other equipment with sponges, absorbent pads, towels or disposable cloths.

- **Brushing or scraping;** this method uses physical movement to remove a contaminant in both dry and wet decontamination scenarios, e.g. using a coarse brush to remove contaminated debris from fire boots.
- **Isolation and dispersal;** a two-step process in which contaminated articles are first removed to, and isolated within, a designated area by “bagging and tagging” the articles. The bagged articles are then further packaged in a suitable transportation container for disposal at an approved hazardous waste facility.
- **Vacuuming;** involves the use of vacuums to collect a range of contaminants including hazardous dusts, fine powders etc. The vacuum must be designed and approved for this specific application. High Efficiency Particulate Air (HEPA) filters physically capture the contaminant but must be replaced frequently.

NOTE: The use of vacuums in fire related incidents may not be effective for wet personal protective equipment and clothing.

- **Evaporation or gassing-off;** the process via which contaminants are left to evaporate or gas-off. The effectiveness of this method can be limited for porous surfaces for very large quantities of materials (National Operational Guidance (NFCC), 2020).



Wet (chemical) decontamination

These methods generally involve removing contaminants by some type of chemical process. They are typically conducted over a dam which is designed to contain the run-off (for larger numbers of firefighters, a Hughes shower may be more appropriate). At the end of the process, the Environment Agency should be consulted to identify the most appropriate disposal method for the run-off (National Operational Guidance (NFCC), 2020).

Wet decontamination methods include:

- **Dilution/washing;** uses cold/warm water, or soap and water solutions to flush the contaminants from protective clothing and equipment. The use of soap or detergents helps to remove oils, greases, dirt, grime, etc.

- **Chemical degradation;** the process of altering the chemical structure of the contaminant through the use of a second chemical or material. Commonly used degradation agents include calcium hypochlorite bleach, sodium hypochlorite bleach, sodium hydroxide (household drain cleaner), sodium carbonate slurry (washing soda), calcium oxide slurry (lime) etc. Chemical degradation is primarily used to decontaminate structures, vehicles and equipment and should **not** be used on chemical protective clothing, and **never** applied directly to the skin. Technical advice must be obtained from product specialists to ensure that the solution used is appropriate for the specific contaminant.



- **Solidification;** a process by which a contaminant physically or chemically bonds to another object. This method is primarily used to decontaminate equipment and vehicles. Commercially available solidification products can be used for the clean-up of spills (National Operational Guidance (NFCC), 2020).

Effectiveness of Decontamination Methods

Studies on the effectiveness of various decontamination methods have shown that no single decontamination method is successful in removing all (100%) of contamination (Figure 39). However, some methods have been found to be more effective than others (National Operational Guidance (NFCC), 2020). Generally, methods that use some form of scrubbing with detergent appear to be more effective. Additionally, methods which use hose reels or main jet/spray branches appear to out-perform portable shower units, when used alone.

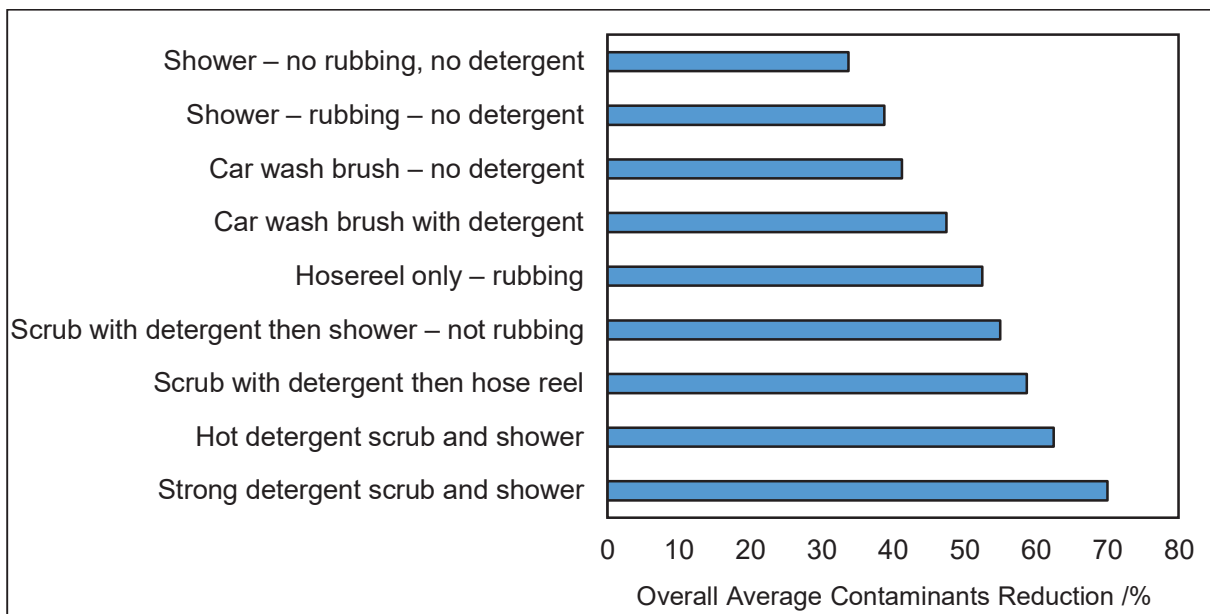


Figure 39: Effectiveness of decontamination methods, as studied by the Home Office Fire and Research and Development Group (1995) (National Operational Guidance (NFCC), 2020)

No single decontamination method will work for every hazardous materials incident. Therefore, a variety of different methods may be needed for effective decontamination.

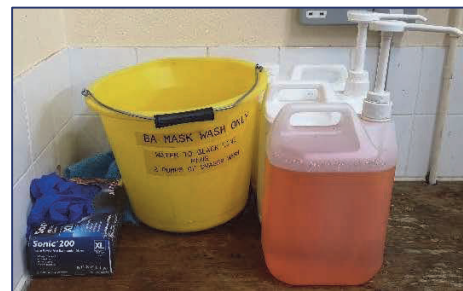


Decontamination Equipment

A variety of equipment is available to facilitate the kinds of decontamination methods described above. It is recommended that this equipment be stored together as a portable set for easy access at incidents. In the USA decontamination buckets as a pre-packaged “kit” available for purchase are becoming popular. While similar products may not be currently available in the UK, it may be valuable to replicate the concept. For information the list below details the contents of a typical decontamination bucket available in the US. UK FRSs may wish to adopt this approach and assemble their own.

Decontamination buckets should ideally be stored in every appliance, and should contain (Hamilton County Fire Chiefs Association, 2018):

- Laminated set of decontamination notes
- 1 x 25-30 Litre bucket with the lid and sides labelled DECON KIT
- 2 x disposable (breathable) dust and waterproof clothing (overalls) (consider also gas or liquid tight suits to cover BA)
- Barrier tape, poles, cones or signs
- Disposable latex or nitrile gloves
- 2 x packs of “Fire Wipes” or “Baby Wipes” for wiping face, neck, arms and hands
- 2 x bottles of water
- 1 x soft and hard brush for removing fire debris such as insulation fibres and soot
- 5-10 Litre plastic pump sprayer or 1 x 15 foot section of garden hose with adapter for discharge with nozzle
- 4 gear bags or 200 Litre (minimum 6 millimetre thick) rubbish bags to put contaminated gear into
- Bag of cable zip ties
- 1 x bottle of Dishwashing detergent
- 1 x bottle of multipurpose cleaner concentrate
- Labels and permanent markers.



In addition to the decontamination bucket, the following items should also be available:

- 2 x large PVC liners for dam (disposable)
- pH paper (roll)
- Water containment system and pump
- Dry encapsulation material (Fuller's earth)
- 2 x blue oil absorbent pads (disposable)
- 2 x yellow chemical absorbent pads (disposable)
- 1 x pack of paper towels (disposable)
- Megaphone (to assist decontamination)
- 1 x 750 mL Grease Off degreaser spray



Decontamination Areas

Decontamination methods should be conducted within designated areas (both at fire incidents and at the fire station). This ensures that contaminants and hazardous waste are properly contained and avoids re-contamination.

Cordons and zones

At any fire incident where hazardous materials are released or suspected, strict cordon control is essential to managing contamination. Cordons are an effective method of controlling resources and maintaining safety on the incident ground. They may be defined by a series of markers (e.g. cones, traffic tape, etc.) and must be continuously monitored and adapted to reflect changes in hazards, weather etc. (see considerations for designating decontamination areas below) (National Operational Guidance (NFCC), 2020).

Cordons should be designated on arrival of the FRS to an incident as part of the control, safeguarding and coordination of an immediate response. Designation of cordons should consider and encompass several specific “zones” (see Figure 40):

- **HOT ZONE**; where contaminants are generated and released - poses an immediate health and safety threat to all located within the zone. Entry to this zone should be restricted to the minimum numbers of people for work to be undertaken safely and effectively. Effective PPE required for working within the ‘hot’ zone.
- **WARM ZONE**; contaminants are not generated in this zone, but may still enter the zone via the movement of people or vehicles. Represents a lower immediate risk to health and safety compared to the hot zone.

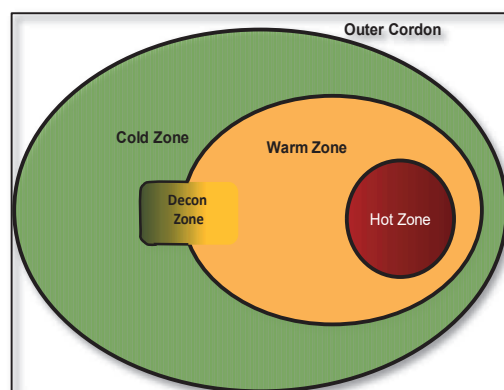


Figure 40: Zones within the decontamination area

- **COLD ZONE**; free from contaminants. It is the area within which key operational command positions and other essential activities will be set up (National Operational Guidance (NFCC), 2020).
- **DECON ZONE**; the decontamination (decon) zone forms the interface between the cold and warm zones (Figure 41). It is set-up in the cold zone on the boundary of the warm zone and at minimal travel distance from the hot zone. It contains FRS (and possibly other emergency service) decontamination staff, equipment and structures (Figure 41 example and typical layout). The decontamination zone should be established by the commander **before** crews are committed into the hot zone. Decontamination equipment should be set up by crews wearing firefighting PPE. Once set up, only personnel wearing the appropriate PPE will be permitted to enter and operate inside this zone (National Operational Guidance (NFCC), 2020).

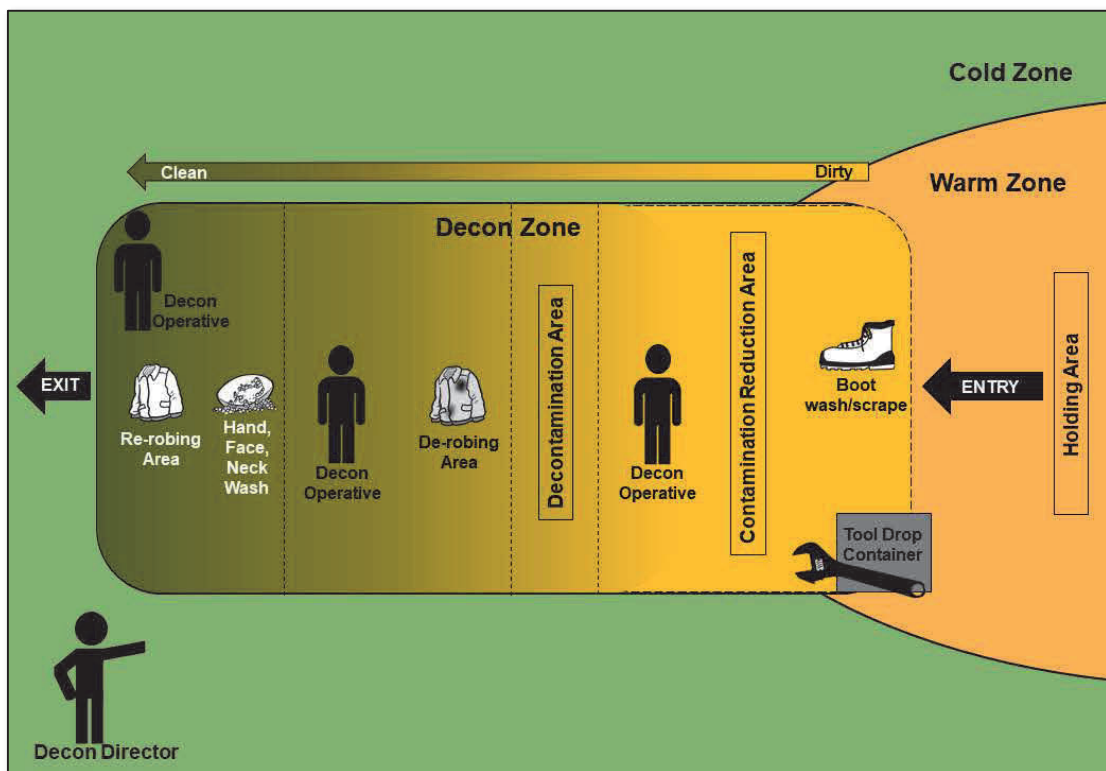


Figure 41: Typical layout of the decontamination zone. The layout presented above aims to minimise the spread of contaminants. However, this layout may need to be altered as appropriate to the specific fire incident and decontamination procedures.

General Considerations for Decontamination Areas

When choosing locations to designate as decontamination areas at the fire incident, the following should be taken into account (National Operational Guidance (NFCC), 2020):

- Type and level of contamination.
- Weather conditions (temperature, precipitation, etc.).
- Access/egress routes to/from the hot zone.
- Wind direction.
- Slope of the ground.
- Location of breathing apparatus entry control.
- Location of a pumping appliance, and availability of hose reel for washing off and damping down.
- Sufficient distance from the hot zone to the decontamination area to ensure that no airborne contamination can reach the decontamination area.
- Surface material and porosity (grass, gravel, asphalt, etc.).
- Availability of water.
- Location of drains, sewers, and watercourses.
- Access for oncoming vehicles.
- Likely numbers of personnel requiring decontamination.
- Welfare of staff (hydration).



Once a location has been designated as a decontamination area, the following should be taken into consideration when preparing the area for decontamination methods:

- Containment of wash-down water and run-off.
- Accessibility of a spare supply of breathing air (extra SCBA).
- Accessibility of a supply of industrial-strength rubbish bags.
- Clearly marking specific boundaries within the decontamination area (i.e. not just by laying a rope on the ground).
- Clearly marking entry and exit points, ensuring the exit point is upwind and away from the incident and contaminated areas.
- A waiting location at the entry point where contaminated personnel can await their turn for decontamination without spreading contamination further.
- Protection of personnel from adverse weather conditions.



Decontamination Team and Protective Clothing

Knowledgeable personnel (decontamination officers, incident commanders etc.) should pre-determine the type of incident, level of decontamination and decontamination methods required during incident preparation.

The decontamination process requires a team of dedicated personnel to conduct successfully. For initial decontamination this team may simply take the form of a “buddy” system, whereby two firefighters assist each other with initial decontamination or decontamination reduction efforts. For full decontamination this team should be comprised of several specialist operatives, including a Decontamination Leader/Officer/Director (appliance commander), Dirty and Clean Operatives and Support (crew) members.

The role of **Decontamination Leaders/Officers/Directors** should include:

- Assessing types of contaminants and contamination level
- Ensuring correct set-up of the decontamination zone
- Instructing crews on the most appropriate decontamination methods
- Nominating roles for each crew member and ensuring they have correct PPE
- Supervising wet decontamination methods and preparing required decontamination solutions with chemicals/ additives
- Safeguarding contaminated staff
- Remaining outside of the decontamination area
- Informing the Incident Commander* when the team and the decontamination zone is set up and ready to accept personnel for decontamination.

**Only the Incident Commander can declare the decontamination zone open, but they should take guidance from the decontamination leader.*

The role of **Dirty/Clean Operatives** should include:

- Remaining within the appropriate areas of the decontamination zone to prevent cross-contamination:
 - Clean Operatives should remain within the clean areas of the decontamination zone, and should wear disposable suit, breathing apparatus and chemical resistant gloves.
 - Dirty Operatives should remain within the dirty areas of the decontamination zone and should wear chemical protective clothing and breathing apparatus (cylinder or airline).
- Acting on the directions of the decontamination leader/officer.

The team leader will advise on the most appropriate PPE for decontamination operatives which, in most circumstances, will be disposable, breathable, dust and waterproof clothing (overalls), full face mask with appropriate filters, neoprene gloves, gas or liquid tight suits and clean BA.



Waste and Disposal

The decontamination process generates several forms of contaminated, potentially hazardous waste. It is important that this waste is contained and disposed of appropriately:

- Waste from decontamination may contain persistent organic pollutants which may lead to the environmental damage. Any waste / run-off must be contained either in waste bags or the decontamination dam.
- Contaminated wipes, nitrile gloves, suits or any other disposable items should be double bagged in plastic bags for appropriate disposal by specialist hazardous materials recovery contractors. If these contractors are not present, then this waste should be handed over to the local authority.
- Equipment shown as disposable should be disposed of on scene if the item has been used.
- All equipment **unused**, or not identified as disposable (and which has been decontaminated if used), should be returned to station in order to be re-used.
- Each fire appliance should have one decontamination equipment box.

- A stock of spare equipment should be kept at the station to immediately replace items used at an incident.

Any runoff from decontamination methods that is not contained will eventually enter sewers and water courses, or if it sinks into the ground will ultimately reach the water-table. It is therefore important to contain this run-off and dispose of it appropriately.



Decontamination good-practice considerations

There are number of considerations that have to take place during decontamination process. If they are poorly carried out it can lead to a further unnecessary health hazards. These are:

- Where appropriate, crew should assist each other in rinsing off debris and products of combustion in a systematic and thorough manner (starting from the collar line and working down).
- During the decontamination process visual and audio communication will be restricted. All personnel should therefore be fully aware of decontamination procedures, and should face each other and stand on the spot during the process.
- Personnel carrying out decontamination should make sure they are properly hydrated (both prior to and after the process).
- Caution needs to be taken when entering the decontamination zone, especially where this involves stepping up onto, and off of, a mat or raised platform, and where the use of water introduces the risk of slips, trips and falls.
- Decontamination should be conducted from top-to-bottom, i.e. starting at the collar line or helmet and working down.

Hands and face should be washed (with soap or by using wipes), especially before firefighters handle any food or drink.

- Loss of air supply during the decontamination process should to be carefully considered **before** decontamination starts. Members with the lowest air supply should be decontaminated first. Where possible, personnel should remain under air until the decontamination process is complete.
- Respiratory protective equipment should be the last item removed in safe undressing procedures (see an example of a full safe undressing procedure).
- Personnel should be careful not to saturate the inner lining of the PPE. PPE should be kept operationally dry on the interior, while the exterior is rinsed cleaned. Soft bristle scrub brushes and department-approved soap/cleaner may facilitate the cleaning process.
- Areas most likely to accumulate contaminants should receive special focus when wiping, scrubbing, brushing or spraying PPE e.g. creases, folds and joins in chemical protective clothing, under webbing or straps etc. Care should be taken not to force contaminants beneath the layer of personal protective equipment.
- Zips and other joins in personal protective equipment and chemical protective clothing should be sponged before they are opened to avoid water entering the wearers' base layer
- If personnel who are not wearing protective clothing become contaminated – they must replace their clothing, remove contamination from exposed locations (e.g. by wiping or washing) and shower as soon as possible. If any health symptoms occur medical advice should be sought.

Appliance tank water or any water used in the decontamination process must come from a clean, municipal (hydrant) water source, not from a stagnant or potentially contaminated water source.

An Example of Safe Undressing Procedure for Emergency Decontamination of Personnel in Firefighting PPE

The below example is replicated from London Fire Brigade's decontamination procedures.

SAFE UNDRESSING PROCEDURE	
	<p>Nominate roles:</p> <ul style="list-style-type: none"> • Decontamination Leader/Officer • 2 x Decontamination operatives. • Minimum of 1 Support Staff.
Decontamination operatives:	<ul style="list-style-type: none"> • As a minimum don FPS 7000 face mask with P3 filter and neoprene or other reusable gloves. • Consider the use of a loud hailer. • Avoid kneeling down, and carry out the safe undressing procedure at arm's length to prevent unnecessary contact with the wearer. • Ensure the outside of suit does not touch the wearer during disrobe. • If any obvious cross contamination is observed immediately report it to seek decontamination advice.
Wearer:	If necessary, use your gloved hands to lean on operatives for support
Support Staff	Lay out a salvage sheet beside the wearer to provide a 'clean path' onto which to stand. Also, provide a charged hose-reel set on flush.
Wearer	Step into reusable bag with operatives' assistance if required.
Decontamination operatives	<p>If the wearer is wearing BA maintain the face mask seal and remove the BA set from the wearers shoulders – one operative should continue to support the weight of the BA set whilst the second operative continues the disrobe process.</p> <p>Move BA to a hanging rack.</p>
Decontamination operatives	Remove wearers helmet and gloves and place clear of wearer – instruct wearer not to touch contaminated firefighting PPE with unprotected hands, even in an attempt to assist in the disrobe.
Decontamination operatives	Provide wearer with nitrile gloves ensuring they are donned unfasten Velcro on fire tunic fully and then unfasten zip. Remove tunic from shoulders – <u>ensuring tunic is turned inside out as removed.</u>
Decontamination operatives	Grasp the cuff of the tunic and instruct the wearer to withdraw their arm – remind them of the need to work their thumb out of the thumb loop.

	Remove nitrile gloves and then place their arm across their chest <u>without coming into contact with contaminated clothing</u> . Repeat on other arm. (If necessary, use your gloved hands to lean on operatives for support)
Decontamination operative(s)	Keep tunic inside out and place clear of the wearer.
Decontamination operative(s)	Pull fire hood over the head (from back to front) being careful not dislodge BA face mask. Allow fire hood to remain looped around the supply hose of the BA set.
Support Staff	Provide dis-robe pack and wearers footwear if available.
Decontamination operative(s)	Remove leggings braces from shoulder and allow to fall to waist.
Decontamination operative(s)	Roll down leggings – inside out – to boot level. Grasp each boot, in turn, and instruct wearer to step from boot onto salvage sheet.
Decontamination operative(s)	Remove wearers face mask and reset first breath button on lung demand valve.
Wearer	Move away from decontamination zone for assessment by Incident Commander
Wearer (if showered)	Should then dry themselves and dress using the dressing packs provided or other alternative clothing
Leader	Ensure that ensure that BA sets, helmet, fire-coat, gloves, boots and leggings are double bagged and sealed with cable ties. Emergency decontamination gloves should be removed, double bagged and sealed.
ALL:	Check for any areas of exposure, then dress and proceed to breathing apparatus entry control and then complete any necessary records. If suspected of cross contamination (in fire kit and SCBA) then proceed to the decontaminated process as described above.
ALL:	As a final precaution wash hands and face.
Additional Point:	If required, responders who have completed the safe undressing procedure should be directed to the Ambulance Service for monitoring and / or medical care.

Table 7: Example of a safe undressing procedure during the decontamination process.



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