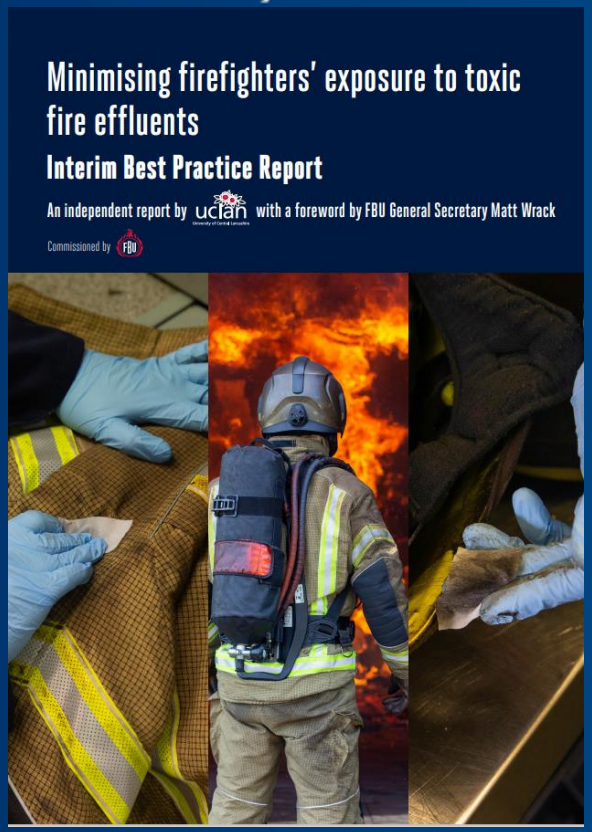
Northumberland
County Council



FIRE BRIGADES UNION

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Contaminants, Toxicity and Exposure Pathways

- 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.

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

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

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.

61% of UK serving firefighters who responded indicated they have problems with their sleeping.

(FBU & UCLan National Firefighter survey)

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.

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

(FBU & UCLan National Firefighter survey)

Recommendations
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.

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

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

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.*

CONTAMINATION: CONTROLLING AMOUNT AND EXPOSURE TO TOXINS

- **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.**

- **What can be controlled to some extent is the amount (or "dose") of fire effluents which firefighters are exposed to.**

Contamination Types

Surface contamination occurs when contaminants are present on the outer layer of a material but have not been absorbed into the material . 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. If not removed, contaminants may continue to permeate further through the material. Factors that influence permeation include:

- **Temperature** - Increase temperature = increase in permeation.
- **Contact time** - Increase time = increase in permeation.
- **Concentration**- Increase in concentration = increase in permeation.
- **Chemical and physical properties** - Low viscosity gases and liquids = increase in permeation.

Contamination Types

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.

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.

Designated Zones

	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.