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Working Group Paper for the National Fire Chiefs Council prepared by the Centre for Applied Science Technology

A summary of the literature provided to the Centre for Applied Science and Technology (CAST) regarding the potential long-term health effects of smoke contamination on firefighter Personal Protective Equipment (PPE)

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Press enquiries relating to this working group paper should be passed to the NFCC Press Media Team.

Summary

This working group paper has been prepared by the Home Office Centre for Applied Science and Technology (CAST) in collaboration with the Personal Protective Equipment Contaminants Working Group (PPEC WG), led by the National Fire Chiefs Council (NFCC). The NFCC commissioned CAST to summarise the literature and information available with regards to the potential long term health effects associated with smoke contamination on firefighter personal protective equipment (PPE).

There is interest to further explore the evidence in this area following international reports, which purport an increase in the relative risk of occurrence of cancer in firefighters, particularly in regard to whether a potential link exists between, smoke contamination on PPE and an increased relative risk of cancer. The NFCC working group have initiated a project to review the evidence in relation to UK firefighting practices and to consider appropriate next steps if required.

There are a number of complexities when considering the potential health effects associated with smoke contamination of PPE. These include: the complex chemical environment of fires; the fact that the data on current cancer rates does not reflect current UK practices; the conflicting nature of the literature and the complexity of assigning cancer risk to specific activities with limited direct evidence. It is therefore, not possible to either prove or disprove a link specifically between smoke contamination on firefighter PPE and a potential increase in relative risk of occurrence of cancer.

CAST recommends that further research is undertaken to understand any potential risks, utilising subject matter experts, experimentation and other methods to inform the decisions by the NFCC working group regarding the future direction of the work.

This working group paper does not purport to be an exhaustive consideration of literature and work in this area, but a summary of limited literature and information reviewed by CAST. This working group paper has been peer-reviewed by the Netherlands Institute of Safety (IFV), an independent international government body. The IFV support the recommendation in the paper for further work to be undertaken in this area, to inform the future direction.

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1. Introduction

The Home Office Centre for Applied Science and Technology (CAST)¹ was commissioned by the National Fire Chiefs Council (NFCC) to initiate a project to investigate and provide:

- a better understanding of any potential risks highlighted in literature for the long term health effects to firefighters, as a consequence of any retained contaminants within their Personal Protective Equipment (PPE); and
- guidance and recommendations to the UK Fire and Rescue Service, with regards to the potential next steps that may be needed to mitigate any risks that may exist.

The preliminary review of the literature and information only considered the first point, in trying to assess and define the problem, using the three strategic questions:

1. What is the international problem we are here to understand?
2. Does the UK have an equivalent problem?
3. To what relative extent does the UK have a problem?

The strategic questions were further developed by the PPEC WG to assess specifically the likelihood of increased cancer rates for the firefighting profession and if this can be linked to smoke contamination of PPE directly. The thematic questions are detailed in section 2.

This work was supported by the PPEC WG including representatives from:

- NFCC (Senior Responsible Officer)
- Home Office (including CAST)
- Health and Safety Executive (HSE)
- Fire Brigades Union (FBU)
- Fire Officers' Association (FOA)
- Retained Firefighters Union (RFU)
- Kent Fire and Rescue Service

¹ www.gov.uk/government/publications/centre-for-applied-science-and-technology-an-introduction-june-2017

- NFCC UK Research and Development (UK R&D) Programme

This preliminary review of the literature was undertaken between November 2016 and March 2017 and the complete list of literature reviewed is detailed in Appendix A. This summary does not give a comprehensive overview of the literature.

There are a few fundamental issues which should be kept in mind from the outset when interpreting the literature and drawing conclusions. The reviewed data looks at the current published rates of cancer which may be linked to historical exposures within the firefighter population, over the last 30+ years. Decontamination and operational exposure practices have improved during this time, advancements in PPE and its issue may vary across the UK, therefore the effectiveness of current practices will not be reflected in any cancer rate data for a number of years to come².

Much of the literature reviewed reflects practices in other countries; therefore, the conclusions cannot necessarily be applied to the UK especially given that a number of factors could be different including: the building materials, firefighting practices and issued PPE.

When examining firefighter cancer rates in literature, a comparison is normally made to the general population cancer rates³. However, there are a number of factors that differentiate firefighters from the general population e.g. working in extreme temperatures, exposure to diesel fumes and disruption to normal sleep pattern (circadian rhythms) caused by shift work. The International Agency for Research on Cancer (IARC), at the time of writing this paper, classified shift work as being “probably carcinogenic to human” (IARC, 2007). This is the second highest classification that the IARC gives (with the highest being “carcinogenic to humans”); therefore, consideration should be given as to whether firefighters should be compared to a general population that are shift workers in order to give a fair comparison. It is not being suggested that shift work is responsible for any increased cancer rates in firefighters, or that it is the only factor that affects the risk level, this point is merely to illustrate the difficulties in trying to associate a specific activity with an increase in cancer risk.

² In addition to working practices other factors including lifestyle choices may influence cancer rates.

³ General population cancer rates are aged standardised which is the most common way of reporting cancer statistics. They are generally used to compare populations and overcome the problems caused by different age profiles.

2. Summary of the literature

2.1. Approach

The literature provided by the PPEC WG does not purport to be an exhaustive literature review. The list of reviewed literature is shown in Appendix A.

The literature was reviewed against a series of thematic questions detailed in Sections 2.2 to 2.6. These questions sought to identify whether the literature supported or opposed the specified themes.

This summary has been peer-reviewed by the Netherlands Institute of Safety (IFV), an independent international government body who completed their own literature review between 2015 and 2016, The IFV support the findings and recommendations in the paper for further work to be undertaken in this area.

2.2. Do firefighters have a higher incidence of cancer?

Cancer is one of the top causes of death in England and Wales, accounting for five out of the top ten causes of death among males (ONS, 2013). According to Cancer Research UK (2017), incidencies of cancer among the population are rising each year, increasing over 30% since the 1970s. When looking at the likelihood of cancer for persons in the firefighting profession, only data from males has been considered. This is due to a lack of female data available in the literature, and the data from males and females not being comparative.

In order to determine whether firefighter PPE practices are increasing the risk of a firefighter developing cancer later in life, it is first important to determine whether a firefighter does indeed have a higher likelihood of cancer.

Following examination of a number of studies (Appendix A), it is difficult to form a firm conclusion on whether or not firefighters are at higher risk of developing cancer when compared to the rest of the population. Different studies appear to show conflicting information; however, specific types of cancer have been reported as having a higher relative risk than the general population but not at the level, deemed to be “more likely than not” by the Institute of Occupational Medicine (IOM).

For cancer to be associated with the firefighting profession, the Institute of Occupational Medicine states that there needs to be evidence showing it is “more likely than not”, so the risk must be more than doubled, otherwise a positive connection cannot be associated with the profession (Graveling, *et al.*, 2010).

Graveling, *et al.* (2010) performed a review of 34 different papers to establish whether there was a link between the firefighting profession and cancer within the UK. It was noted that both positive and negative associations with cancer were claimed in the reviewed papers. Of the

various cancers examined, a higher than normal association was seen with skin cancer, prostate cancer, colon cancer, rectal cancer, testicular cancer, bladder cancer, multiple myeloma and lymphatic and haemopoietic cancers. However, the higher than normal association for all cancers never exceeded 1.5 times and was well below twice the risk of the general population, the rate at which a positive trend could officially be declared.

The findings of another review by LeMasters, *et al.* (2006) largely agrees with the findings above stating that there is probably an increase risk of multiple myeloma, non-Hodgkin lymphoma, prostate cancer and testicular cancer associated with being a firefighter.

2.3. Is there contamination present on the PPE of firefighters when they leave a scene?

Whilst fighting both building (structural) and vehicle fires, firefighters are exposed to a vast number of different chemicals as well as smoke particulates (Alexander, 2012). These chemical and particulate deposits will populate the surface of the PPE during exposure and remain once the scene has been exited.

Historically in the United States, there have been reports that some firefighters viewed the contamination of their PPE as a sign of experience, and wore their soiled equipment in order to gain respect from their peers (Alexander, 2012).

The Fire Brigades Union believes contamination on PPE may be an issue post-fire, suspecting contamination with a variety of volatile organic chemicals (Carrington, 2016).

2.4. What contaminants are present?

There are numerous studies into the identification of the various contaminants present on firefighter PPE. It is important also to note that the contamination present will vary according to the type of fire and materials being burnt (Pukkala, *et al.*, 2014). Synthetic materials which are commonplace in house fires produce toxic gases including irritants and asphyxiants (Giebultowicz, *et al.*, 2016) which inevitably the PPE will be exposed to.

Huston (2014) conducted an investigation in order to identify and quantify some of the contaminants present on firefighter PPE upon exiting a scene. It was found that hydrocarbons, polyaromatic hydrocarbons, plasticisers, trace metals and ethers were present on the PPE (Huston, 2014). During a study into the occurrence of cancers among firefighters, NIOSH & NORA (2011) lists asbestos, arsenic, benzene and formaldehyde among other chemicals as common combustion products which are likely to be present at a fire scene.

2.5. What are the potential effects of the contamination?

The most common immediate effects of the contamination found in a fire are asphyxiation (Giebultowicz, *et al.*, 2016) and irritation; however, these effects occur because of immediate, short-term exposure.

It is known that long-term exposure to polyaromatic hydrocarbons can increase the chances of developing cancer later in life (Boffetta, *et al.*, 1997). However, studies looking into the long-term effects of specific chemicals mostly relate to industrial exposure rather than from the exposures within the firefighting profession.

Other chemical contaminants found on the PPE (identified in section 2.4) are also known to have long-term health implications and this information is available through accessing the material safety data sheet (MSDS). This particular source of information is an already well-established field of research so further studies in this area would provide limited benefits.

2.6. How much contamination is present on the PPE?

There are limited numbers of sources which measure the level of contaminants on firefighter PPE post-event, and even fewer which look into the resulting off-gassing⁴ concentrations. During experimental work, it was found that following exposure to the contaminants, PPE off-gassed volatile chemicals into the atmosphere for up to 25 minutes, although the levels recorded were well below the occupational exposure limits (Fent, *et al.*, 2013).

A study was conducted by Merseyside Fire and Rescue Service (Carrington, 2015) to measure the levels of contaminants off-gassing from contaminated PPE which firefighters are exposed to when leaving the fire scene and returning back to the fire station. The study found that the exposure, based on one set of contaminated PPE, was less than the working exposure limits for all volatile organic chemicals examined. However, a limitation of the study would be that it did not look into the cumulative effect of the concentration when multiple sets of contaminated PPE are transported simultaneously.

Alexander (2012) reported microgram levels of contamination per swatch of PPE; however, this was measured by dissolving the contaminants from a swatch of PPE and therefore does not give an indication of off-gassing levels.

⁴ Off-gassing refers to the release of volatile chemicals in the form of gas; non-volatile chemicals (such as asbestos) will not off-gas

3. Conclusions

Based on CAST's initial review of the information and the complex causal nature of risk assignment, it is not possible to prove or disprove a specific link between smoke contamination on firefighter PPE and an increased relative risk of cancer as a result of the limited direct studies. From the studies examined in this review, there is evidence to show that contamination is present on PPE after a fire; however, there are limited studies which look at the off-gassing effects or concentrations of the contaminants. Where the evidence shows the off-gassing concentrations, the studies are on a small scale and do not take into account the real-life scenarios, therefore it is hard to draw firm conclusions. Further studies are required to understand the potential risk based on UK firefighting practices.

To ascertain if there is a link between contaminated PPE and an increased relative risk of cancer, a study conducted over a significant period of time would have to be undertaken, in addition to an extended literature review but there is still a risk that this may not result in a definitive conclusion. Such studies would also very likely need to involve subject matter experts, a recognised cancer organisation and risk assignment body to give any recommendations.

Between the period of review and issuing this update CAST are aware of new or imminent publications from active researchers in this field by:

- Institute of Occupational Medicine (IOM) – published September 2017
- Institute for Safety (IFV, Netherlands) – awaiting translation
- University of Central Lancashire (UCLAN) – published February 2018

CAST will provide a further summary for the PPEC WG of the documents listed above once available.

Whilst this is being considered, it is suggested that, in parallel, further research activities investigate the levels of contamination associated with UK firefighting practices. This could include:

- establishing fuller details on what contamination is present from real-life scenarios and off-gassing effects
- how the contamination exposure could be reduced (if applicable) in practical terms by looking at:
 - the current standard operating procedures and identifying other potential routes of exposure to contamination (e.g. during 'over-haul' stage)
 - how they can be further reduced if necessary through training and different techniques.

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**Home Office Science
Centre for Applied Science and Technology**

Sandridge
St Albans
AL4 9HQ
United Kingdom

Telephone +44 (0) 1727 865051

Fax: +44 (0) 1403 213627

Email: cast@homeoffice.gsi.gov.uk

Website: <https://www.homeoffice.gov.uk>