Institut de recherche
Robert-Sauvé en santé
et en sécurité du travail

Epidemiological Literature Review on the Risk of Cancer among Firefighters

Corrected Version

Paul G. Brantom
Ian Brown
Marc Baril
Roseanne McNamee

STUDIES AND RESEARCH PROJECTS

R-1012

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IRSST – Communications and Knowledge Transfer Division
505 De Maisonneuve Blvd. West
Montréal, Québec
H3A 3C2
Phone: 514 288-1551
publications@irsst.qc.ca
www.irsst.qc.ca

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Corrected Version

Paul G Brantom, Consultant in Risk Assessment, UK
Ian Brown, University of Oxford, UK
Marc Baril, University of Montreal, Quebec
Roseanne McNamee, University of Manchester, UK

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Erratum

Page ii: Small intestine was removed from the summary table and the 4th line in the paragraph below the table.

Page 74: The text and the table were modified to the effect that no statistically significant association was found between cancer of the small intestine and the occupation of firefighter in the Daniels et al. (2014) study.

Page 81: The paragraph on small intestine was modified to conclude that there was no new evidence of an association between small intestine cancer and the occupation of firefighter.

Page 82: Degree of statistical association for small intestine was changed to "None", and "Quality of evidence for association" and "Chemical exposure association" cells text replaced by grey background.

Pages 83 and 84: Reference to cancer of the small intestine was removed from the 3rd and last paragraph of section 5.2.

This study was funded by the IRSST. The conclusions and recommendations are solely those of the authors.

PEER REVIEW
In compliance with IRSST policy, the research results published in this document have been peer-reviewed.

EXECUTIVE SUMMARY

A review of the literature on cancer in firefighters, published since the IARC review of 2007, was undertaken to establish any new evidence for associations of occupation of firefighter with cancer, or pointers to possible associations. The review gave attention to 21 cancer sites indicated inconclusively by previous reviews.

In total, more than 600 publications on exposure and epidemiology were screened for data related to cancer in firefighters. From these papers 11 key studies were identified to provide primary epidemiological data and a further 14 supportive case-control studies were selected. Every study screened and rejected is detailed in an annex to the report, with a brief reason for exclusion, as part of the comprehensive reporting of the review.

The studies of firefighters reported in this review cover long periods of employment (up to 40 years) with some large cohorts and therefore provide useful additions to the data previously available.

The studies identified were summarised and scored for quality, and conclusions were reached for each of the 21 cancer sites, taking account of the results of the study and the plausibility of an association, based upon the known chemical exposures of firefighters. The combined evidence for each specific site was classified in two dimensions: one which focused on the presence of statistically significant associations of cancer with the occupation of firefighter (None, Limited, Mixed, Consistent) and the second which was based on the qualities of the study, the existence of a plausible mechanism and a demonstration of a trend with categories: Very weak, Weak, Moderate, Strong.

The classifications for those cancers where a statistical association was seen are summarised in the table below. The outcome is compared with the conclusions of the previous review by IARC.

Because this study spanned a limited publication time-frame with a limited number of sometimes small studies, addressing a particular cancer, it was unlikely to be able to provide strong statistical evidence and thus to definitively link cancers with occupation. The evidence is limited in part by the number and the quality of the available studies but also by the lack of availability of comprehensive data on specific exposures for each firefighter. A more limited objective of assessing existence of new pointers or suggestive evidence was possible.

The conclusions of this report are based only on the evidence published since 2007 plus a few published slightly earlier which did not get included in the IARC review. In particular, no attempt has been made to review and integrate all published evidence to date. A full assessment of the evidence for association and risk for a specific cancer type would require a full review of all available data for that cancer type, with a meta-analysis of data from all studies, to increase the statistical power of the investigation. The evidence of association for each cancer type reported here is based on the limited publication date- range covered by this review and conclusions are necessarily limited by this.

Based upon the current review there is the strongest evidence for an excess of mesothelioma for those who were employed as a firefighter more than 30 years ago, probably as a result of asbestos exposure. Lung cancer is not as strongly associated but is known to be linked to the same exposures, so cannot be ruled out as occupationally related. There is no conclusive evidence for association of any other cancer type with the occupation of firefighter, however, NHL and prostate cancers have been found more frequently in firefighters in both the current review and in that made previously by IARC (2010a).

SUMMARY OF THE CONCLUSIONS ON CANCER AND FIREFIGHTERS			
Site	**Degree of statistical association**	**Quality of evidence for association**	**Previous IARC Conclusion (IARC, 2010a)**
Bladder	**Limited**	**Weak**	
Brain	**Mixed**	**Weak**	Not confirmed*
Colon/rectum (large intestine)	**Mixed**	**Very weak**	Not confirmed*
Head & Neck (including larynx and pharynx)	**Limited**	**Weak**	
Kidney	**Mixed**	**Weak-moderate**	
Leukaemia – all types	**Limited**	**Weak**	
Lung	**Mixed**	**Weak-moderate**	
Mesothelioma	**Consistent**	**Strong**	
Multiple myeloma	**Limited**	**Very weak**	Not confirmed
Non-Hodgkin lymphoma (NHL)	**Mixed**	**Moderate**	Possible (approximately 20% excess)
Oesophagus	**Mixed**	**Weak**	
Prostate	**Mixed**	**Moderate**	Possible (approximately 30% excess)
Skin – melanoma	**Mixed**	**Weak-moderate**	Not confirmed*
Skin – non-melanoma	**Limited**	**Very weak**	

*Site indicated by meta-analysis (LeMasters et al., 2006), but not confirmed by IARC

Note: No data are available on cancer latency specific to firefighters thus a latency period of > 10 years is assumed for most cancers while for lung a period of >20 years and for mesothelioma a period of >30 years are consistent with Internationally agreed figures, although mesothelioma has occasionally occurred after a shorter period.

Apart from mesothelioma, the data available from the current review was insufficient to fully conclude or to rule out any associations between cancer and occupation. There is some evidence of an association between occupation of firefighter and cancers of bladder, brain, colon/rectum, head & neck, kidney, oesophagus and skin together with leukaemia and multiple myeloma. Cancer at some of these sites (brain, colon/rectum, skin) has been indicated as potentially linked to occupation of firefighter by a meta-analysis carried out in 2007, but not by IARC. The occupational association with cancers at the other sites identified in this review is not supported by the previous reviews, thus no further conclusion can be drawn.

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LIST OF ABBREVIATIONS AND ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
BMI	Body Mass Index
CAS	Chemical abstracts service number
CeVD	Cerebrovascular disease
CI	Confidence interval
COPD	Chronic obstructive pulmonary disease
DFG	Deutsche Forschungsgemeinschaft
EU	European Union
HR	Hazard ratio
IARC	International Agency for Research on Cancer
IHD	Ischaemic heart disease
ISCO	International Standard Classification of Occupations
NHL	Non-Hodgkin lymphoma
OR	Odds ratio
PAH	Polycyclic aromatic hydrocarbons
PPE	Personal protective equipment
RIR	Relative incidence ratio
RR	Rate ratio
SIR	Standardised incidence ratio
SMOR	Standardized morbidity odds ratio
SMR	Standardized mortality ratio
SRR	Standardised rate ratio
SS	Statistically significant

1. INTRODUCTION

1.1 Background

Firefighters are potentially exposed to a wide range of hazardous substances during their working lives. Over time protective clothing and equipment has improved to reduce the chances of significant exposure to these hazards, especially during knockdown, compared with the overhaul or clean-up phase. The exposure potential may be greater during the clean-up phase following a fire, when the use of protective clothing and equipment may seem less essential.

There is concern amongst firefighters and their representatives that the occupation of firefighting may be associated with an increased risk of cancer.

In view of the concern about cancer risk the subject has been considered previously by the Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST) who, in the last decade, have published a number of reviews of cancer amongst firefighters looking at colon & rectum (McGregor, 2007a), leukaemia (McGregor, 2007b), multiple myeloma, cancers of the respiratory system, oesophagus, stomach, pancreas, prostate, testes and skin (McGregor, 2007c), non-Hodgkin lymphoma (McGregor, 2007d), brain (McGregor, 2005a), kidney (McGregor, 2005b) and urinary bladder (McGregor, 2005c). More recently the International Agency for Research on Cancer (IARC) has published a review of cancer incidence among firefighters (IARC, 2010a). This review reached the conclusion that occupational exposure as a firefighter is possibly carcinogenic to humans, (Group 2B). The data reviewed suggested increased risk for some cancers, particularly of testis, prostate and non-Hodgkin lymphoma (NHL). However, the combination of poor characterisation of exposure, (only by duration of employment), and a lack of reproducibility in the identification of increased incidence at specific target sites, prevented any specific or more definite conclusions.

The present review is based on those studies relevant to cancer in firefighters, published since 2007, when the IARC review was completed, although a few papers published in that year, but not cited by IARC, have also been included.

Inconsistency of firefighter cancer compensation between different compensation boards in North America has raised concern amongst stakeholders of the Québec compensation board.

In 2016, most Canadian provinces/territories have established legislated presumptions for compensation of firefighters: British Columbia, Alberta, Manitoba (first province to establish a legislated presumption list, in the 2004-2005 legislature), Saskatchewan, Ontario, New-Brunswick, Nova Scotia, Newfoundland & Labrador (autumn 2016), Yukon, Northwest Territories, and Nunavut. Thus, only Prince-Edward Island has not yet agreed to do so for now.

Although the Quebec compensation board has compensated firefighters for many years for job-related cancer, no policy, as required by the legislation, has been accepted by the board of administration in that regard. The aim of the present review is to support the board to establish such a policy.

1.2 Firefighters: General characteristics of exposures and absorption

According to data cited in previous IRSST reports (McGregor, 2005a; McGregor, 2005b; McGregor, 2005c; McGregor, 2007a; McGregor, 2007b; McGregor, 2007c; McGregor, 2007d) approximately 90% of structural fires are either extinguished, abandoned or fought from outside within 5 - 10 min with the average duration of heavy physical activity being 10 min (Gilman and Davis, 1993).

Firefighting is normally described in the literature as a two-phase operation. The first phase is ensuring the fire is brought under control and this is known as 'knockdown', the second phase is when the fire is extinguished and the firefighters then look for more occult fire sources, perhaps inside attics, ceilings and walls and then secure the site; this clean-up phase is known as 'overhaul' and may be undertaken without respiratory protection (Bolstad-Johnson et al., 2000; Burgess et al., 2001). These remarks from authors some fifteen years ago are still valid today in many services. During overhaul, firefighters frequently remove their respiratory protection (Baxter et al., 2014) or do not always wear self-contained breathing apparatus during that phase of fire management, (Fent et al., 2013). It is noted that this is not the case any more in the Montreal fire-brigade, where respiratory protection is mandatory during overhaul (personal communication from officers and firefighters, Fire-station 43; 2016).

In terms of occupational industrial hygiene, based on recent literature, a third phase needs to be considered which could be described as after-fire clean-up at the fire-station. It is discussed (Fent et al., 2015) that firefighters and their clothing and equipment, (see below), may have absorbed benzene, toluene, ethylbenzene, and xylenes, through both the dermal route during firefighting, supporting previous observations, (Caux et al., 2002) and by inhalation, which has already been demonstrated (Bolstad-Johnson et al., 2000; Austin et al., 2001).

Firefighters also have the potential for inhalation exposure when off-gassing their personal protective equipment (PPE) after firefighting. This is especially so when traveling in confined vehicles with contaminated PPE or when they clean up equipment after reaching their base and should take measures to minimize this potential exposure pathway, (Kirk and Logan, 2015). Exposures to contaminated air may also occur in the fire-house rest area and kitchen, routinely adjoining the truck bay, and where firefighters spend a major part of each shift (Baxter et al., 2014).

Using different industrial hygiene techniques, some authors have measured the compounds to which firefighters are exposed in different situations. Data has come from either measurement in air during phase one, two or three, swabs of skin and equipment and from biomonitoring. The results are presented in the following referenced table (Table 1).

Table 1: Compounds consistently found in municipal structural fires or vehicular fires by swabs of skin, in sampled air or by biomonitoring

Substances/CAS	ACGIH Class	Cancer site (ACGIH/IARC)	IARC Cancer classification	References
1,2-butadiene 590-19-2	NA		NA	(Austin et al., 2001)
1,3-butadiene 106-99-0	A2	Lymphopoietic cancer	Group1	(Austin et al., 2001)
1-4 dichlorobenzene 106-46-7	NA	Liver	Group 2B	(Fent et al., 2015)
1-butene/2-methylpropene 563-46-2	NA		NA	(Austin et al., 2001)

Table 1: Compounds consistently found in municipal structural fires or vehicular fires by swabs of skin, in sampled air or by biomonitoring

Substances/CAS	ACGIH Class	Cancer site (ACGIH/IARC)	IARC Cancer classification	References
1-methylcyclopentene 693-89-0	NA		NA	(Austin et al., 2001)
2-methylbutane 78-78-4	NA		NA	(Austin et al., 2001)
Acenaphthylene 208-96-8	NA		NA	(Baxter et al., 2010)
Acetone 67-64-1	NA		NA	(Fent et al., 2015)
Acrolein 107-02-8	A4		Group 3	(Bolstad-Johnson et al., 2000)
Arsenic 7440-38-2	A1	Lung, urinary bladder, skin, kidney	Group1	(Easter et al., 2016)
Alkyl-substituted benzene compounds	Carcinogenic: Function of components			(Austin et al., 2001)
Benzene 71-43-2	A1	**Sufficient evidence in humans:** Acute myeloid leukaemia/acute non-lymphocytic leukaemia. **Positive association:** Acute lymphocytic leukaemia, chronic lymphocytic leukaemia, and non-Hodgkin lymphoma	Group1	(Bolstad-Johnson et al., 2000; Austin et al., 2001; Caux et al., 2002; Fent et al., 2015)
Benzofluoranthene 205-82-3/207-08-9 205-99-2	A2	NA	Group 2B	(Baxter et al., 2010)
Cadmium 7440-43-9	A2	Lung, prostate	Group1	(Easter et al., 2016)
Carbon monoxide 630-08-0	NA		NA	(Bolstad-Johnson et al., 2000)
Chromium 7440-47-3	A1	Lung, nasal cavity and sinus	Group1	(Easter et al., 2016)
Cyclohexane 110-82-7	NA		NA	(Fent et al., 2015)
Cyclopentene 142-29-2	NA		NA	(Austin et al. 2001)
Ethylbenzene 100-41-4	A3	NA	Group 2B	(Austin et al. 2001)
Formaldehyde 50-00-0	A2	Nasopharynx and leukaemia *(not as strong as nasopharynx)* Positive association has been observed between exposure to formaldehyde and sino-nasal cancer.	Group1	(Bolstad-Johnson et al., 2000; Driscoll et al., 2016)
Glutaraldehyde 111-30-8	A4		NA	(Bolstad-Johnson et al., 2000)
Isopropylbenzene 98-82-8	NA	Lung or nasal tumours in rodents and possibly in humans	Group 2B	(Austin et al. 2001)
Methoxyphenols	NA		NA	(Fernando et al., 2016)
Naphthalene	A4	NA	Group 2B	(Austin et al.,

Table 1: Compounds consistently found in municipal structural fires or vehicular fires by swabs of skin, in sampled air or by biomonitoring

Substances/CAS	ACGIH Class	Cancer site (ACGIH/IARC)	IARC Cancer classification	References
91-20-3				2001; Baxter et al., 2010)
Perfluorinated chemicals (PFOA)	NA	Positive association was observed for cancers of the testis and kidney	Group 2B	(Dobraca et al., 2015)
Polynuclear aromatic hydrocarbons (PNA's) coal tar pitch volatiles	A1	Skin, lungs, kidneys	Group 1	(Bolstad-Johnson et al., 2000)
Polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and dioxin-like polychlorinated biphenyls (PCBs)	Carcinogenic: function of components	Lung and all cancer sites (combined) (2,3,7,8-tetrachlo-rodibenzo-para-dioxin) Leukaemia and/or lymphoma	Group 1	(Hsu et al., 2011; Chernyak et al., 2012)
Polycyclic aromatic hydrocarbons (PAH)	Carcinogenic: function of components		Group 1	(Caux et al., 2002; Fent et al., 2013; Fent et al., 2014; Fernando et al., 2016)
Propane 74-98-6	NA		NA	(Austin, Wang et al. 2001)
Propene 115-07-1	NA		NA	(Austin et al. 2001)
Styrene 100-42-5	A4	Possibility of lymphatic and haematopoietic neoplasms	Group 2B	(Austin et al., 2001; Fent et al., 2015)
Toluene 108-88-3	A4		Group 3	(Austin et al. 2001)
Ultrafine particles	NA		NA	(Baxter et al., 2014; Evans and Fent, 2015)
Xylene mixture 1330-20-7 108-38-3(m) 95-47-6 (o) 106-42-3 (p)	A4		Group 3	(Austin et al., 2001; Austin et al., 2001)

NA - Not assessed
ACGIH Classification: A1 – Human carcinogen; A2 - Suspected human carcinogen; A3 - Confirmed animal carcinogen with unknown relevance to humans; A4 - Not classifiable as a human carcinogen
IARC Classification: Group 1 - Carcinogenic to humans; Group 2B - Possibly carcinogenic to humans; Group 3 - Not classifiable as to its carcinogenicity to humans

As cited in IRSST documents (McGregor, 2005a; McGregor, 2005b; McGregor, 2005c; McGregor, 2007a; McGregor, 2007b; McGregor, 2007c; McGregor, 2007d), just 14 different compounds accounted for about 75% of the total volatile organic materials measured (Austin et al., 2001). These same compounds constituted approximately 65% of all volatile organic compounds in experimental fires, burning various materials commonly found in structural fires (Austin et al., 2001). The spectra of volatile organic compounds were dominated by benzene, which is classified as carcinogenic to humans, along with toluene and naphthalene by many different agencies IARC[2], ACGIH[3], DFG[4] and the EU[5]. They also found that propylene and 1,3-butadiene, which is classified as carcinogenic to humans by IARC, were present in all the fires. Styrene, classified as Group 2B, by IARC, and other alkylated benzenes, were frequently identified.

Asbestos (IARC Class 1 and ACGIH Group 1) exposure is presumed, although there is no direct analytical evidence of exposure. This naturally occurring fibrosilicatious mineral is still to be found in numerous buildings and was historically used as a fire-retardant and insulator. It was often located in fire-doors and around boilers and pipes. Since 1992 it has been illegal to use asbestos to make new products in the UK and in 1999, the selling and fixing of asbestos containing materials in the UK was also banned. In Canada, the regulatory situation is different and there is presently no ban on the use of asbestos. However, in May 2016, the Canadian Government announced that it would be moving towards establishing a Canadian ban of asbestos use.

When left undisturbed in a building, it is often safer to leave it *in situ* rather than attempt a removal procedure, which will create an aerosol of asbestos fibres. Asbestos, when inhaled, can cause several very serious, usually pulmonary conditions, including asbestosis, lung cancer and mesothelioma (predominantly of the pleura of the lung). The very nature of the work of firefighters will inevitably expose them to asbestos and the incidence of lung-related conditions, especially mesothelioma, has been found to be significantly greater in firefighters than in the comparator population[6]. The mechanism of cancer causation has been well described and is a product of the nature, shape and durability of the asbestos fibre (which is often long and thin), rather than the chemical nature of the mineral.

1.3 Co-exposures, including shift work

Co-exposures may include elements such as diesel fumes and heavy physical work, but no evidence was found among the retrieved information to support any impact of these on cancer rates in firefighters. Shift-work may be considered as a co-exposure, which can have the potential to affect the cancer risk in firefighters. It is important to this assessment since it is thought to increase the risk of certain cancers and the prevalence of shift-work among firefighters is high compared to the general population in most countries. In fact, anecdotal reports suggest that nearly all front-line firefighters might work shifts but the many studies addressing cancer risk include workers who are not front-line *e.g.* fire inspectors and fire investigators thus the prevalence in this wider job group is of interest. A brief review of the survey literature in four countries was carried out for this report and revealed variation between surveys.

Variations in reported prevalence may to some extent be explained by the form of the question asked, *e.g.* “do you ever” versus “do you regularly”. Also, the meaning of shift-work may have been explained differently to respondents in these surveys. (*e.g.* the statistics quoted for France refer to night-work, defined as working, even partially, between 12.00am and 5am). Reports which address shift-work prevalence by occupation tend to group them with other occupations, usually other “protective services”. In the 2005 Canadian Survey of Labour and Income

[2] International Agency for Research on Cancer

[3] American Conference of Governmental Industrial Hygienists USA

[4] Deutsche Forschungsgemeinschaft (Germany)

[5] European Regulation, (EU) on classification, labelling and packaging (CLP) of substances and mixtures

[6] (Mesothelioma Occupation Statistics, Male and female deaths aged 16-74 in Great Britain, 2002-2010, http://www.hse.gov.uk/statistics/index.htm)

Dynamics, as reported by Demers in 2010[7], 54% of men and 32% of women in Protective Services worked ‘rotating /evening /night shifts’ versus 19.5% and 17.2% for the general population. If the definition is extended to include those who work ‘irregular schedules’ the figures are higher (firefighters make up 10% of protective services, in Canada). In these population surveys, too, those who are classified, or classify themselves, as firefighters may include some people who are not considered front-line firefighters. This may mean that the true prevalence among front-line workers is likely to be higher than the averages quoted for all those classified as ‘firefighters’.

The figures quoted below are for occupations that are jointly described as ‘protective services’. This group includes police officers but the largest subgroup may be security guards. Again, different countries may set the inclusion criteria of this larger group differently, e.g. some include armed forces, while others do not. The UK does not include senior managers in protective services under this label, while others (USA) appear to do so. As shown below shift-work prevalence figures for protective service occupations in four countries range from 45 to 72%. The firefighter group probably makes up only 10% of this larger group and thus these figures can only be taken as estimates of prevalence for firefighters. The source data are briefly summarised below.

Canada

Figures identified for shift-work for male protective service workers were 54% (Demers, 2010)[8], 66% (Williams, 2008) and 70% (Sunter, 1993). Canadian census data indicate that firefighters comprise around 10% of protective services workers.

US

Two different sources identified that the proportion of protective workers working on a shift basis was 61% (Princeton, 1991) or 50.6% (USDL, 2005). Data from a recent USA census indicate that firefighters comprise around 9% of protective services workers.

France

A recent government report (Dares, 2014) states that 73% of the army, police, firefighters work at night.

UK

Among males within the personal protection occupational group, a consistent proportion of at least two-fifths reported working any patterns of shift work in their main job (UK-HSE, 2011). The years 2001 and 2006 contained the highest proportions of shift work among males in the personal protection occupations, with 47.4 % and 46.9 % of workers engaging in any form of shift work respectively. Data from the 2011 census indicate that 9.4% of those included under protective services are ‘fire service officers (watch manager and below).

Whether shift-work acts as a confounder of any association between chemical exposures and cancer depends on the study design. For example, if a study compared cancer rates in firefighters and police officers, it might be that the prevalence of shift-work was approximately equal in both groups; in such a study, shift-work is not a confounder. However, most studies

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[7] https://www.iwh.on.ca/shift-work-symposium/demers

[8] https://www.iwh.on.ca/system/files/documents/shift_work_2010_demers_presentation.pdf

compare firefighters with the general population. In these studies, one would expect that there would be an increase in the Rate Ratios (RR) among firefighters for any cancer causally associated with shift-work. It is useful to quantify the degree of increase expected in these general population comparator studies.

Example of quantification of shift-work impact on apparent cancer rates

Suppose there is no effect of chemical exposures on prostate cancer risk (*i.e.* the true RR = 1), but the RR for prostate cancer incidence among shift workers in general is 1.8. If the prevalence of shift-work among firefighters is 60% while it is 15% in the general population, then we might expect to see an RR of 1.32[9] for firefighters.

[9] 1.32=(0.4+0.6*1.8)/(0.85+0.15*1.8)

2. METHODOLOGY

The present review is based on those studies relevant to cancer in firefighters, published since 2007, when the IARC review was completed, although a few papers published in that year, but not cited by IARC, have also been included.

The primary objective has been to review all the publications retrieved, paying attention to additional data relating to potential target sites identified during previous reviews. It was outside the scope of this exercise to combine this additional data with those of the IARC review or other prior reviews. The search for new data excluded publications on childhood effects, non-cancer end-points and on firefighters working primarily in wildfire environments or those specialists who determine the causes and origins of fire (arson investigation). Factors that may impinge on cancer rates in firefighters, such as shift-work and detailed work/clean-up practices, were not explored as a primary search topic but are considered in the review as potential factors in the interpretation of the epidemiological data.

2.1 Literature review procedures

The main literature review process included a search for observational epidemiologic studies about cancers in relation to firefighting in major bibliographic databases (Analytical Abstracts, BIOSIS Toxicology, CAB ABSTRACTS, Current Contents Search, Embase, PASCAL, ProQuest Dissertations and Theses Professional, PubMed, TOXLINE).

The full detail of the search process is included in Annex 1.

2.1.1 Inclusion and exclusion criteria

Articles published since late 2007 (2007 was the last year of publication considered in the monograph published in 2010 by IARC); peer-reviewed literature; published in English or French or translated into these languages.

Excluded case reports, childhood cases (child OR children), non-cancer end-points, wildfire-fighters.

Two strategies were used for information retrieval (one for firefighters and the other for specific cancer sites), with the following keywords.

Firefighters:

(Cancer OR Carcinogenesis OR Neoplasm OR Metastasis OR Tumor OR Tumour) AND (Firefighter OR Fire fighter OR Fireman OR Firemen) AND (Epidemiologic OR Epidemiology OR Epidemiological OR Fatality OR Incidence OR Mortality OR Morbidity)

Site or type of cancer:

(Organ or Site of cancer) AND (Cancer OR Carcinogenesis OR Neoplasm OR Metastasis OR Tumor OR Tumour) AND (Epidemiologic OR Epidemiology OR Epidemiological OR Fatality OR Incidence OR Mortality OR Morbidity) AND (Employee OR Employment OR Manpower OR Occupation OR Personnel OR Occupational OR Staff OR Work OR Worker OR Workman OR Workmen OR Workplace OR Worksite).

The sites of cancer searched were:

Bladder, Bone, Breast (in men), Brain, Colorectal, or colon rectum, Head & neck (mouth, pharynx, oropharynx) Kidney, Leukaemia, Larynx, Lung, Mesothelioma, Multiple Myeloma, Non-Hodgkin lymphomas (NHL), Oesophagus Pancreas, Prostate, Skin, Small intestine, Stomach, Testicles, Thyroid.

Exposure:

Because the intention was to present all substances firefighters are exposed to during a fire, from leaving the fire station to back to the station after the clean-up phase, we retrieved all articles published on the subject since 2001. The following bibliographic databases were looked at initially in April 2016: Analytical Abstracts, Biosis toxicology, CAB Abstract, Current Contents search, Embase, Pascal, Proquest Dissertations and Theses Professional, PubMed and Toxline. There were no restrictions on the language of publication.

Single terms used for the research were: firefighter, fire fighter, Firefighter (MESH), fireman, firemen, pompier, sapeur pompier and sapeur-pompier. Single terms used for exposure were: Exposition, characterization, exposure, exposures and occupational exposure (MESH).

The same research protocol was used again in October 2016 to retrieve any new articles published since April

2.2 Selection of studies

The approach taken to this review in selection and judgement of studies is as described in the *Preamble to IARC opinions* adopted and published in 2006[10] and summarised briefly in the paragraphs below.

The epidemiological data selected in the literature search are mainly cohort and case-control studies with the case-control studies being selected if they relate to cancer at sites indicated by previous reviews as potentially relevant to firefighters. Non-cancer end-points and benign cancers are generally not included.

All retrieved papers have been reviewed for mention of firefighters or relevant job descriptions or occupation codes. In many publications firefighters are categorised under ISCO-08 as 541 and this has been used to check reports where codes are used and descriptions are unclear. Where alternative codes (*e.g.* National classification) have been used, these have been checked for relevance to firefighters. Where studies make no mention of firefighters or exposures expected to be relevant to firefighters these have been rejected and are not included in this review. A full list of rejected publications is provided as Annex 4 to this report.

2.3 Judgement of studies and causality

The observation of an increased cancer rate in an occupational group compared to a comparison group is insufficient on its own to reach a conclusion of causality. Several other criteria must be met, including reasonable certainty that confounding, other bias or misclassification of exposure or outcome does not explain the observed results. These bias issues, as they affect studies of firefighters, are elaborated further in section 2.4 and the Newcastle-Ottawa scale, a formal system which has been proposed to evaluate some of these issues in published studies, is discussed in section 2.5.

[10] http://monographs.iarc.fr/ENG/Preamble/

The role of chance is also important to interpretation and is usually addressed through calculation of confidence intervals or a statistical significance test. Application of these methods gives rise to a classification of results as either statistically significant or not. For clarity, these concepts are described in section 2.6. A judgement that there is a causal association, as opposed to a statistical association, normally also requires a plausible explanation of mechanism linking exposure and disease and observation of the result in more than one study. Section 2.7 addresses how the combined evidence from all the studies were assessed using all these criteria and the categories used to classify the evidence for each site.

2.4 Bias and confounding

2.4.1 Confounding by non-occupational factors

Since many of the comparisons in the studies reviewed are made with the general population differences in lifestyle-related factors such as smoking, alcohol consumption, obesity could bias the outcome of the comparisons. The relevance of these factors for each study is mentioned in the reporting of each of those studies but some general background data suggest that such factors may not be a major source of bias.

2.4.1.1 Alcohol

Firefighters are recognised to represent an at-risk drinking group. This is one of many studies that have demonstrated that alcohol consumption is greater in the fire service and particularly in the active, emergency-responding, firefighter. Alcohol has also been clearly implicated as causing an increased risk of several cancers. Meta-analysis found that alcohol most strongly increased the risks for cancers of the oral cavity, pharynx, oesophagus, and larynx. Statistically significant increases in risk also existed for cancers of the stomach, colon, rectum, liver, female breast, and ovaries (Bagnardi et al., 2001). IARC reported alcohol to be potentially associated with cancer of oral cavity, pharynx, larynx, oesophagus, liver, breast and colon/rectum (IARC, 2012).

2.4.1.2 Smoking

Based on a review of data from some of the studies retrieved on firefighters there is a tendency for firefighters to smoke slightly less than the general population, although the degree varies between countries. On the other hand, a recent study found little difference from the general population in whether firefighters had ever smoked but those who accumulated 20 or more pack-years were a higher proportion (by about 5%) for firefighters. In the aggregate, these reports suggest that smoking differences are small but because the Rate Ratio for lung cancer among moderate to heavy smokers is high (15 or more (Dela Cruz et al., 2011)), it is of interest to assess the impact of small differences in prevalence. Suppose there is no occupational exposure among firefighters which increases lung cancer risk (*i.e.* the true RR = 1), but smoking prevalence is 35% versus 30% in the general population, if the RR for lung cancer among smokers is 20, then we might expect to see an RR of 1.14 for lung cancer among firefighters versus the general population. If the prevalence were reversed, the RR would be 0.88.

IARC (IARC, 2012) concluded that the following cancers relevant to this review are associated with tobacco smoking:

lung, oral cavity, naso-, oro- and hypopharynx, nasal cavity and accessory sinuses, larynx, oesophagus, stomach, pancreas, colon/rectum, liver, kidney (body and pelvis), ureter, urinary bladder, and myeloid leukaemia.

2.4.1.3 Obesity

Based on a review of data from some of the studies retrieved on firefighters there may be a small excess of overweight firefighters compared to the general population in some countries (US and UK), but not in other countries, but the excess is not great. Heart disease was still the most frequent cause of death among on-duty firefighters between 1994 and 2004, (Kales et al., 2007), and a review of 3,450 injury cases within the US concluded that 29% were the result of a lack of fitness. This will increase their rates for some outcomes, but we expect this also to be true for the general population. According to the US cancer society[11], being overweight or obese is clearly linked with an increased risk of cancers of the colon, oesophagus, kidney and pancreas and possibly cancers of the gallbladder, liver and non-Hodgkin's lymphoma (NHL). A recent British study which estimated RRs for an increase of 5 kg/m^2 in Body Mass Index (BMI) for each of these cancers, gave figures in the range 1.10-1.30 (Aune et al., 2016). If firefighters had an average BMI 2 kg/m^2 higher than the general population this might lead to RRs of approx. 1.04-1.12.

2.4.1.4 Medical examination frequency

The periodic medical examination of firefighters is mandatory in several services, as a minimum level of fitness is required to undertake the job. How often this is undertaken depends on the local fire-service requirements. The London Fire Brigade (LFB) in England requires a medical examination every three years. There are similar practices in Canada (Occupational Health Evaluation Standard)[12] and the periodic examination is every three years up to 30, every two years from 30 to 39 and annually thereafter. Such periodic examination should detect the early signs of cancer and thereby may reduce mortality for some cancers, as early treatment and follow-up will be implemented.

2.4.1.5 Ethnicity

Rates of some cancers vary by ethnicity, for example in the US rates for lung cancer are substantially reduced in Hispanic men (RR=0.5 versus non-Hispanic white men) while rates of cancer of the stomach, liver and gall bladder and acute lymphocytic leukaemia are significantly increased. If the ethnic distribution of firefighters is the same as in their comparator group in a study (*e.g.* general population), there will be no confounding from this factor. In studies where the ethnic distribution is not matched between controls and study population confounding may still be avoided by controlling for some genetic and lifestyle factors.

2.4.2 Shift-work

In an evaluation of the relationship between a specific chemical compound and cancer in firefighters, other exposures and work practices may act as confounders. As described in section 1.3, shift-work is common among firefighters and is also associated with some cancers.

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[11] http://blogs.cancer.org/expertvoices/2013/02/28/the-obesity-cancer-connection-and-what-we-can-do-about-it/?_ga=1.250611014.1524518412.1482853242

[12] https://www.tbs-sct.gc.ca/pol/doc-eng.aspx?id=12561&section=HTML

Whether shift-work acts as a confounder of any association between chemical exposures and cancer depends on the study design. For example, if a study compared cancer rates in firefighters and police officers, it might be that the prevalence of shift-work was approximately equal in both groups; in such a study, shift-work is not a confounder. However, most studies compare firefighters with the general population. In these studies, one would expect that there would be an increase in the Rate Ratios (RR) among firefighters for any cancer causally associated with shift-work. It is useful to quantify the degree of increase expected in these general population comparator studies.

2.4.3 Other biases

2.4.3.1 Inclusion criteria to be classified as a firefighter

Where the concern is with the impact of chemical exposures, front-line firefighters are the workers of most interest. However the definition of a 'firefighter' varies between studies: in some it is fairly loose, e.g. includes supervisors, fire-investigators, as well as front-line firefighting, and in others more specific. One study found that only 66% of fire-department personnel in Montreal were front-line firefighters (Austin et al., 2001). Where studies can provide proxy exposure measures, *e.g.* number of fire-runs, a loose initial inclusion criterion may not matter as more focused subgroups within the larger group can be identified. But in studies without good proxy exposure metrics, the specificity of the inclusion definition should be borne in mind.

2.4.3.2 New hires versus cross-sectional inclusion criteria for cohorts

In a classic cohort design, firefighters would be followed up from the date of first joining the fire service. However, some cohort studies include workers who were in post on a certain calendar date (which is typically when record keeping began) and follow these only from that point. The latter has been called a cross-sectional inclusion criterion; as opposed to new hires only. Some cohort studies include both types of approach: *e.g.* all those in post on 1/1/1970 and new hires thereafter (Applebaum et al., 2011). The authors concluded that, if there is heterogeneity in susceptibility to the effect of an exposure, cross-sectional inclusion hire criteria induces a downward bias in RRs.

2.4.3.3 Healthy worker selection effect: malignant versus non-malignant diseases

Mortality/morbidity rates for certain diseases, especially cardiovascular, are often expected to be less than in the general population in the early years of follow-up of a cohort. This is because the general population includes economically inactive people, some of whom are too ill to work, whereas initially, occupational cohorts do not. Furthermore, for a workforce such as firefighters where there are specific health-related entry criteria, the health differential in the early years after hire may be quite big. This aspect of the healthy worker effect complicates interpretation of studies that compare with any general population group which include economically inactive people. Comparisons with rates for another workforce who are subject to similar health-related entry criteria but with no specific hazards or with hazards for different health problems, would avoid this problem. However, an important question relevant to this study is whether we expect a similar 'healthy hire' effect for cancer incidence. This was addressed by comparing cancer incidence rates in a random sample of newly hired Norwegian workers over a period of up to 20 years afterwards with rates in the general population; the authors found statistically significant reductions for all cancers (Standardised Incidence Ratio, SIR=0.91) and for cancer of the bladder (SIR=0.77), head and neck (SIR=0.78), kidney (SIR=0.83), leukaemia (SIR=0.80), lung (SIR=0.81), oesophagus (SIR=0.60), pancreas (SIR=0.85), prostate (SIR=0.93) and thyroid

(SIR=0.78), but not for brain (SIR=1.04), colorectal (SIR=0.95), mesothelioma (SIR=1.11) multiple myeloma (SIR=0.94), NHL (SIR=1.04), skin (SIR=1.09), small intestine (SIR=1.00), stomach (SIR=0.94) and testis (SIR=1.04) (Kirkeleit et al., 2013). The authors concluded that there was marked potential for underestimation of some cancer risks when the general population is used as the comparison group. However, 'healthy hire' effects are expected to wear off with time.

2.5 Newcastle-Ottawa scale

To provide some level of objectivity to the assessment of studies the approach described as the Newcastle-Ottawa scale[13] has been applied to the key studies in this review. The scale gives star ratings for the studies for 3 criteria. For cohort studies, the criteria are selection, comparability and exposure while for case-control studies the criteria are selection, comparability and outcome. The manual provided by the authors of the method has been followed as closely as possible, to rate each study of firefighters, but the criteria were modified slightly to suit better the occupational context of this review. The applied criteria are given in Annex 2 to this report. The star ratings are given in detail in Annex 3 for each study of firefighters assessed and are summarised in Table 2 and Table 3 of section 3, and used as part of the overall judgement of the meaningfulness of reported associations.

During the initial application of the scale it quickly became clear that it was not ideal for occupational epidemiology, as it was probably devised with population based, non-randomised studies of therapies in mind. Modifications to address exposure assessment and degree of confounder control were made but a major overhaul would have been required to address other issues we describe here, *e.g.* those in 2.4.3. The development of a new scale and its validation would have been beyond the scope of the present work.

The results from the revised Newcastle-Ottawa assessment scale are nevertheless reported here but, because of the limitations, have not been used further in the overall assessment of evidence. The scale was not applied to studies which considered multiple occupations nor to the Bigert et al. (2016) paper which combined data from multiple studies and does not give sufficient information in the paper to assess the methodologies.

2.6 Chance and statistically significant associations

The strength of a true association between an occupation/exposure and a cancer is measured by the Rate Ratio (RR). In its simplest form, this is estimated from data as the rate among firefighters divided by the rate in a comparison group. On its own, an observation of a RR > 1 – even from a study with little evidence of confounding or other biases - is considered insufficient to reach a conclusion of a causal relationship. One reason is that, due to biological variability, there may be 'chance' increases, or decreases, in cancer rates among firefighters. To address this issue, evidence that the increase is 'statistically significant' is also needed. In this report, evidence of a 'statistically significant (SS) association' in an individual study is said to occur if the Rate Ratio (or equivalent measure) is > 1 and the lower bound of its 95% confidence interval (CI) for the Rate Ratio (RR) is ≥ 1. Among medical researchers, statistical significance is considered a necessary, although not a sufficient condition, for a judgement of causality to be reached. If it is not achieved, the result is said to be 'not statistically significant'.

[13] The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. GA Wells, B Shea, D O'Connell, J Peterson, V Welch, M Losos, P Tugwell http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp

The absence of a SS association in a study is *not* equivalent to a proof of no causal effect. The correct interpretation is that the evidence is insufficient. Indeed, in statistics, a non-significant result is correctly interpreted as a failure to reject the 'null hypothesis', rather than a proof that the null is true.

Statistical significance is a stringent criterion which is difficult to achieve in studies which have low numbers of cases of cancer. This means that small studies could have low 'statistical power' to reach statistical significance even when there are truly causal effects of exposure. In a small study, it is possible that quite a high RR is observed e.g. RR > 2, without being statistically significant (i.e. the lower bound of the 95% CI is < 1). Given that many individual studies in this report are probably underpowered to achieve significance unless exposure effects are large or the cancer is common, it must be accepted that it would be difficult to reach a judgement of causality for some cancers from single studies.

Because of this, assessors might give consideration to alternative, but weaker numeric criteria to highlight 'suggestive' individual results (*e.g.* a lower bound of 0.95 or greater or, preferably, recalculation of 90% confidence intervals). However, acceptance of a greater possibility of false associations (through 'chance') has to go along with such a strategy. Results with a lower bound of 0.95 or greater are given some consideration in the overall assessment of the data here.

An alternative criterion might highlight RRs greater than 2 on the basis that, assuming no bias and ignoring chance, an RR > 2 implied an attributable risk of 50% or greater. Here again one must accept a higher role of chance as an alternative explanation. As few RRs were > 2 this approach was considered but made no difference to the overall assessment.

Ideally, when faced with small individual studies, each with limited power, a meta-analysis which combines numeric evidence and quality indicators from all published studies would be undertaken. In a meta-analysis, a single test of statistical significance is applied to the combined data; this overcomes the problem of low power without increasing the role of a chance association. However, a formal meta-analysis was not part of the primary remit of this review process, but evidence from different studies was considered together, as now described,

2.7 Classification of combined evidence

As discussed above, a judgement that there might be a causal association between exposure and cancer rates would require reasonable assurance that the direction of bias from confounding factors or other sources does not falsely inflate the RR and a demonstration of a statistically significant association.

Another primary requirement for judgement of 'possible' is reproducibility in more than one study. Where there is data from more than one study and a dose-response relationship between incidence and exposure for cancer at any site, the available data are examined in detail in section 4. To move from association of exposure and cancer rate to consideration of causality requires a plausible explanation of the mechanism; this is explored for each cancer showing a clear association with exposure.

Quality of evidence for an effect is firstly based upon the size and confidence limits of the relative risk. However, even a small relative risk can be important if it is reproduced in several independent studies, particularly if the studies involved are of high quality. Causality may also be more readily inferred if risk increases with exposure, particularly if the exposure involves substances already known to be associated with certain types of cancer.

It was recognised that ‘bias towards the null’ from confounding factors or other sources can increase the probability of a non-statistically significant result and thus lower the chance of meeting the usual statistical significance criterion. It is not easy to establish its presence from published papers nor easy to correct for it, but where there is some evidence, it might justify use of weaker numeric criteria to highlight suggestive results. Every effort was made to consider this in the assessment of data and to ensure that potentially important results were not dismissed.

Based on all the issues discussed above, the combined evidence were classified in two dimensions. Firstly, the statistical association of cancer at a site with the occupation of firefighter was classified as either:

None, Limited, Mixed or Consistent

This categorisation is based upon the relative risk found for cancer rates at each cancer site and the frequency of studies showing statistically significant relative risks. Although usual statistical significance rules have been applied, any study result which showed a lower confidence limit > 0.95 is highlighted in grey and such data have been considered in the overall assessment. The basic criteria used are as follows:

None *No new studies showing a statistically significant association or one study which is not corroborated by other data.*

Limited *One or two studies showing a statistically significant association but with more studies showing no association.*

Mixed *More than two studies showing a significant association but with at least an equal number showing no association*

Consistent *The majority of studies conducted showing a significant association.*

Secondly, for those sites showing some statistical associations, the quality of evidence for association is separately categorised as:

Very weak, Weak, Moderate or Strong

These are based upon a subjective assessment of the results of the studies reviewed and the relative quality of the studies showing positive and negative effects. Although individual assessments may vary slightly the main criteria used are:

Very weak *Studies which show an association have weaknesses which could mean that the result is a consequence of a confounding factor. No evidence for trend with duration of occupation. No known exposures relevant to this cancer type. Lower confidence bound ≤ 0.95.*

Weak *Studies which show an association have some weaknesses in design while others of better design show no association. Conclusion is strengthened by trend with duration of occupation and weakened if no known exposures relevant to that cancer type.*

Moderate *Some studies showing an association are of good quality but others have design weaknesses. Conclusion is strengthened by trend with duration of occupation and weakened if no known exposures relevant to that cancer type.*

Strong *Most studies showing an association are of good quality and give consistent results and show some evidence of trend with duration of occupation.*

The latency for each cancer type is generally taken to be > 10 years. No analysis which took account of employment duration showed excess cancer in a group employed for < 10 years. For lung cancer, a period of 20 years is widely accepted internationally, as is a minimum 30-year period for mesothelioma.

The possibility of improving the assessment of specific risks by additional combined analyses may form part of recommendations of the review but, as already mentioned, was excluded from the primary remit of the review process.

3. SUMMARY OF EPIDEMIOLOGICAL DATA RETRIEVED IN THE LITERATURE REVIEW

The 484 publications on epidemiological data retrieved were reviewed for relevance to firefighters and from these, 6 cohort studies on firefighters were identified, described in 8 papers. In addition, 3 case-control studies focusing on firefighters were found. For the cancer sites reviewed, there were 14 other case-control studies which examine general occupational links but mention exposure of firefighters or an exposure pertinent to firefighters. Two of the cohort studies were analysed and reported in more than one paper (Ahn et al., 2012; Daniels et al., 2014; Ahn and Jeong, 2015; Daniels et al., 2015). Two of the three case-control studies in firefighters (Bates, 2007; Tsai et al., 2015) were based upon data from Californian firefighters over a similar time-period thus cannot be considered entirely independent studies. The cohort studies and the three case-control studies have been assessed for quality using the Newcastle-Ottawa scale adapted to these studies are presented in more detail in this section and summarised in Table 2 and Table 3 respectively. The remaining case-control studies have not been formally assessed for quality, as the study quality is not necessarily reflective of the value of the data regarding firefighters. This is primarily due to the small number of firefighter cancers in these studies, but any additional weaknesses of the data have been mentioned. These studies are referred to later in the report (Section 4. Overview of cancer) when the cancer site of relevance is discussed.

3.1 Cohort studies of firefighters

3.1.1 North America

Mortality and cancer incidence were studied in a cohort of 29,993 firefighters of both sexes employed for at least one day between 1st January 1950 and 31st December 2009 (Daniels et al., 2014) (Study 1); this included new hires from 1st January 1950 and those already in employment on that date. The mean age at first employment and total years employed were 29 and 21 years, respectively. The referent population for most of the analyses reported was the US population; however a supplementary analysis reported standardized mortality ratios – SMRs - using the California, Illinois and Pennsylvania State populations as referent (Daniels et al., 2014a). Sensitivity analyses were performed to assess influence of workers employed before 1950, short-term workers and exclusion of workers > 84 years. The results of the mortality analysis identified a significant excess of deaths from all cancers particularly of various parts of the GI tract, kidney and lung, with an excess of mesothelioma and cancer of the buccal/pharyngeal region. The analysis conducted using the California, Illinois and Pennsylvania State populations as referent concentrated only on selected cancers and showed differences between the states, with no significant excess for any cancer in Philadelphia but excess mortality from cancer of oesophagus and rectum in San Francisco and Chicago, and excess of lung and prostate mortality in Chicago. The results were not adjusted for lifestyle habits such as alcohol consumption or smoking. Non-cancer mortality was lower than the referent population apart from cirrhosis and other chronic liver disease (SMR=1.26, 95% CI 1.12 to 1.41, n=299), acute glomerulonephritis with renal failure (SMR=1.56, 95% CI 1.07 to 2.20, n=32). Deaths from falls (SMR=1.31, 95% CI 1.08 to 1.58, n=113) and other accidents (SMR=1.17, 95% CI 1.01 to 1.34, n=197) were also elevated. The excess of the renal and hepatic causes of mortality might be an indication of lifestyle factors or might be due to firefighting work. The mortality data for selected outcomes were further analysed by taking account of the duration of employment and in no case, was there a positive trend associated with the cancer mortality rates seen. Identification of an excess of mortality due to mesothelioma is worthy of note as this cancer is almost exclusively associated with asbestos exposure.

The analysis of cancer incidence rates supported an excess at the same sites as the mortality analysis but also found an excess of urinary bladder cancer; the difference is likely to be due to high survival rates for bladder cancer.

In a second paper, the same authors proposed improvements to the surrogates used for exposure estimation (Dahm et al., 2015) (Study 2). The cohort was now restricted to new hires from 1950 with at least one year of employment; there were 19,423 eligible firefighters with 124 subsequently excluded due to missing or incomplete work history. All the comparisons were internal, between groups defined by exposure. Three approaches were used to define the exposure. The first took account of the number of days where the individual was assigned to active duties rather than those where exposure was deemed unlikely (e.g. office-based). The second used an estimate of the number fire-runs made by each firefighter. Thirdly, this was refined further by estimating the number of hours spent attending fires.

The exposure matrix approach described above was applied to the analysis of mortality and cancer rates for 19,309 firefighters (Daniels et al., 2015). The analyses were conducted only for a selected range of outcomes, based on the previous analysis described above (all cancers, bladder, colorectal, oesophageal, lung, prostate non-Hodgkin' lymphoma and leukaemia). The analysis also included non-cancer end-points of chronic obstructive pulmonary disease (COPD), ischaemic heart disease (IHD), cerebrovascular disease (CeVD) and alcohol-related cirrhosis. Only lung cancer incidence and mortality and leukaemia mortality showed slight but significant association with the exposure parameters used.

3.1.2 Europe

Cancer incidence has been studied in a large cohort of 16,422 Nordic firefighters (Pukkala et al., 2014) (Study 3) from Denmark, Finland, Iceland, Norway and Sweden. Inclusion in the cohort was based on age (16-64) and job recorded by national census of the working population - workers had to be a professional firefighter for more than half regular hours in the census year - and being alive at start of the subsequent year. Cancers in subsequent years were identified from national cancer registries. Due to the 10-year cycle of census data, the study may underestimate the number of years of working as a firefighter. Comparison was with the relevant national population for each country. The study found higher total cancer rates in firefighters, which show different patterns depending upon age, which may, in part, reflect changing practices over time. Particularly notable are higher incidences of skin, prostate and lung cancers including mesothelioma in older workers. The study has some strengths in drawing upon a large population over a long time but only manages to incorporate adjustments for country, calendar-period and age-group; data on other potentially confounding variables were not available.

A cohort of serving Scottish firefighters was followed between 1984 and 2005 (Ide, 2014) (Study 4). During this period, the mean number of firefighters was 2,213 (range 2,173-2,308). The study reported 38 cancers and apart from kidney cancer and melanoma, reported a range of incidences statistically significantly lower than the reference population of men of *similar* age from Scotland or the West of Scotland. The study has limited value, as the denominator for the annual rates appeared to be the size of the serving population. Furthermore, the age profile is unknown apart from between 2001 and 2005 and the comparison was with overall rates for 20-54-year olds, with no attempt to adjust for age differences at a finer level. From the discussion of the results, it appears that 164 leavers were lost to follow-up between 1985 and 1994. Since the age-profile is unknown apart from between 2001 and 2005, there is no opportunity to independently assess the exposure periods for each member. Previous occupational history is known for around 50% of the cohort and some were found to have worked in jobs with the potential for significant exposure to fibrogenic agents, such as silica and asbestos (shipyards, quarries and foundries).

A French mortality study used employment records to identify 10,829 firefighters employed in 1979 throughout France and followed them until 2008 (Amadeo et al., 2015) (Study 5). New hires after 1979 were not included although this is intended in future, but around 49% of those employed in 1979 were less than 30 years old. Comparison was with the French general population, adjusting for age and calendar year only. They found a lower overall mortality rate than the general French population, with SMRs of 0.76 and 0.54 for circulatory diseases and respiratory diseases respectively, suggesting a possible “healthy worker” effect; however, this was a relatively young cohort for a mortality study. The study found no significant excess of cancer of any kind in the firefighter cohort; the overall SMR for cancers was 0.95. Although the results provide some reassurance on the lack of any significant cancer excess the large differences in age-related mortality between control population and the firefighters suggest that a comparison with another working population with similar health selection criteria at recruitment (*e.g.* other emergency services) may have provided a more sensitive analysis.

3.1.3 Australia

A recent study reported cancer incidence and mortality in 17,394 full-time and 12,663 part-time firefighters from eight Australian fire agencies (Glass et al., 2016) (Study 6); the cohorts included both new hires and those already in employment at the start of the follow-up periods. Data on deaths and cancer were obtained by links to the National Death Index and Australian Cancer database respectively. The period covered by this linkage was from 1980 to 2011 for deaths and from 1982 to 2010 for cancers. Expected numbers of deaths were obtained from the Australian population data based on 5-year age groups and sex-specific rates. There was no adjustment for lifestyle factors but firefighters were said to have a higher standard of living than the general population. Duration of employment was categorised into 3 bands (> 3 months < 10 years, 10–<20 years and 20+ years). The overall mortality rate for firefighters was lower than that for the general population (SMR=0.66) with the SMRs of 0.62 and 0.53 for circulatory diseases and respiratory diseases respectively, suggesting a strong “healthy worker” effect. Cancer incidence rates were slightly higher than those of the general population for all firefighters, with only melanoma and prostate cancer showing a significant excess. Although relative incidence rates for melanoma did not show any significant difference, an analysis of the incidence rates compared with the Australian population showed a trend towards higher rates for those employed for longer, with a SIR of 1.50 (95% CI 1.12-1.98) for those with 10-20 years' employment and a SIR of 1.46 (95% CI 1.22-1.75) for those employed for > 20 years. Relative incidence rates (RIR) for full-time firefighters with > 10 years' service was increased for urinary tract and lympho-haematopoietic cancer. This rate was also increased for full-time firefighters with > 20 years' service for kidney cancer and NHL. Part-time firefighters also showed the same increases for kidney and urinary tract cancers.

Data were available on the incidents attended by each firefighter over a limited period, which varied between the agencies; also, workers for whom there were no recorded incidents were excluded from these analyses leaving 12,043 full time and 7,681 part-time workers. An analysis of cancer rates against number of incidents attended compared the upper two tertiles with the lowest tertile. The only cancers showing any relationship to the number of incidents attended were male reproductive and prostate; there were significant trends for prostate cancer for all fire incidents, structural fires and vehicle fires and for male reproductive cancer only for vehicle fires.

Although the assessment of work histories in this study in terms of fire incidents and types of fire was noteworthy, the power of this part of the study to show a significant excess of cancer and mortality was limited due to the short period of follow-up and the relatively young age of the cohort (average age at end of study 49.9 years).

3.1.4 Korea

A study of cancer incidence in a cohort of emergency responders in Korea including firefighters was undertaken (Ahn et al., 2012) (Study 7). These were 33,416 workers consisting of all male emergency responders (ER) employed in the National Emergency Management Agency (NEMA) for at least 1 month between January 1st, 1980 and December 31st, 1995 but alive on 31/12/1995. Follow-up was from January 1st, 1996 to December 31st, 2007 or the date of cancer diagnosis or death. Nine job titles (firefighting, fire-scene investigation, emergency medical aid, technical rescue, driving, piloting a ship, flying, computation and communication, others) were classified into two job categories based on firefighting experience, (firefighter vs. non-firefighter). Non-firefighter ERs comprised 11.9% of the cohort, were on average younger than firefighters and were said to be exposed to the same shift-work as firefighters. Potentially confounding factors (smoking, alcohol and exercise) were obtained by questionnaire responses at annual medical check-ups between 2000 and 2008 for almost 99% of the total cohort, but analyses were not adjusted for differences; ERs smoked less and were less likely to be overweight than equivalent Korean men. Standardised Incidence Ratios (SIRs) and Standardised Rate Ratios, (SRRs) for cancers were adjusted for age and the calendar year of diagnosis. The SIRs were based on a comparison with all Korean men whereas the SRRs compared firefighters with other emergency responders. The authors noted that, during a fire event, the non-firefighter ERs who provide medical aid and technical rescues are also exposed to toxic substances similar to firefighters; both groups are similar in that they work shifts and under intense job stress. Thus, they might be better regarded as a low exposure group rather than an unexposed comparator. Mean age at first entry to cohort was 27.8 years and in 2007 was 41.3 years. In 2007, 84.6% of the cohort were still in active employment. In total, 486 cancer deaths were identified during the period 1996-2007.

Based on the comparison with Korean men, the cohort of firefighters had no significant increase in risk of total cancer, regardless of duration of employment. The SIR was increased for bladder cancer in those who had worked for 10 years or more. The SIR was also increased for colon and rectum and non-Hodgkin' lymphoma but without any relationship to employment duration. The results of the SRR comparison of firefighters with non-firefighters showed no significant differences in cancer rates. All the differences seen in the study were quite small but it is noted that the duration of exposure, age of the cohort and follow-up of this study are relatively small and thus the power to detect significant effects is limited.

A further report addressed mortality rates in a similar cohort (Ahn and Jeong, 2015) (Study 8); included were all those alive on 31/12/1991. There were 444 deaths in total for firefighters; overall mortality rates were significantly reduced (SMR=0.42) compared to the Korean population with SMRs of 0.27 and 0.13 for circulatory diseases and respiratory diseases respectively. There was also a significant reduction in all cancer-related mortality amongst firefighters: SMR = 0.58; 95% CI: 0.50-0.68 compared to the general population. Further analyses examined mortality from stomach, colon & rectum, liver & intrahepatic bile duct, bronchus & lung, lympho-haematopoietic cancers and leukaemia in addition to the total figures. None of the calculated SMRs were significantly higher compared to the control population but some showed significant reductions. Much the same picture is seen for comparisons of non-firefighter ERs with the general population; in this group, the all cancer SMR was 0.55; 95% CI: 0.26-1.01. This study has limited power.

In internal comparisons, mortality among firefighters who had worked 10-20 years and those who had worked > 20 years was compared with a combined group consisting of non-firefighters (ER) and firefighters with ≤ 10 years' employment. There are however, some inconsistencies between results given in this paper, which have not been explained by the authors. For example, the SMR for men who worked > 20 years in firefighting is less than that for firefighters who worked < 10 years and for all non-firefighter emergency responders. But the subsequent internal analysis implies that they had a 50%, statistically significant, increase in risk compared to these two groups, after adjustment for age and calendar period, using a different statistical method. This divergence in results is much greater than would be expected from different adjustment methods. Since there are, in our opinion, serious questions about the accuracy of the later analysis, only the results of the original analysis are cited here.

3.2 Case-control studies focussing on firefighters

The first three case-control studies described here identified both cases and controls from cancer registries, i.e. the control group also have a cancer diagnosis. This is considered to be a valid choice provided that there is no causal association between these other cancers and firefighting. This type of studies might also be viewed as Proportional Morbidity Studies but, following the view of Miettinen and Wang (1981), they are viewed as case-control studies here. Each study investigates links with several cancer sites of prior interest. These three studies are also similar in that all information about occupation comes from cancer registries.

A Massachusetts cancer registry-based study examined the association between some 24 'cancers of concern' and firefighting among white male residents of Massachusetts, aged > 18 years old and diagnosed with cancer between 1987 and 2003, and with sufficient recorded occupational information in the registry record (Kang et al., 2008) (Study 9). Sixty-three percent of all cancer cases have a usual occupation recorded and there were 2,125 cancers among firefighters. The abstract states that controls were "those cancers not associated with firefighters in previous studies" from the same registry although this is not clear from the methods section. The classification as a firefighter was based on usual occupation as recorded by the registry and was quite specific; for example, it excluded 'fire investigator', 'fire inspector' and firemen in industries such as foundries. There were two comparison groups for firefighters: policemen and occupations excluding firefighters and policemen. The comparison with policemen seems preferable in terms of potential for confounding since the latter group undergo similar health selection criteria at recruitment and comes from a similar social background as firefighters. The analyses were adjusted for age and smoking; associations were also shown separately for those aged 18-54 yrs., 55-74 yrs. and 75+ yrs. at diagnosis, as a way of investigating whether there might be bias since some firefighters might retire early and follow another career. They concluded that there was no evidence of this type of bias. The comparisons with policemen showed some evidence of an association of colon and brain cancer rates with the occupation of firefighter, whereas a similar association did not appear when all other occupations were used as the comparator. The age-related analysis indicated that for colon the 75+ category had a stronger association than for other ages (standardized morbidity odds ratio - SMOR 1.73 (1.06-2.84)

In the Californian cancer registry, it appears that there was sufficient detail to classify 87% of male cancer cases aged 21-80 recorded between 1988 and 2003 by occupation (Bates, 2007) (Study 10), there were 3,659 records which had firefighting as the main occupation. The study claimed to investigate links with cancer at sites previously hypothesised to be linked with firefighting. The initial controls were all other cancer cases but, after preliminary analyses, they decided to exclude from the control group cancers of the lung and bronchus, bladder and prostate, colorectal cancers, and skin melanomas. It appears that these then become 'case' groups in their own right, but this aspect of the study is poorly described. In this study, too, in making the classification of a firefighter an effort was made to exclude those who might not have carried out firefighting duties. The comparator for firefighters was all other occupations. Non-Hispanic whites were over-represented among firefighters (91.4%) compared with other occupations (75.3%) but the analyses, adjusted for age, race and socio-economic group identified significantly increased ORs for firefighters for oesophageal, melanoma, prostate, testicular and brain cancer.

A further report of a case–control study used the California cancer registry data, but from 1988 to 2007, updating the results reported above, and using somewhat different inclusion/exclusion criteria and definitions (Tsai et al., 2015) (Study 11). The study included adult males aged 18-97 with sufficient occupational information to classify them; this seems to have been 56% of eligible cases. Control cancers were chosen *a priori*, as sites said to have no association with firefighting or its related exposures; these were cancers of the pharynx, stomach, liver and pancreas. The definition of a firefighter also included supervisors and chiefs, on the basis that such people might have previously worked on the front line. The comparator for firefighters was all other occupations. There were 3,996 firefighters with cancer. The primary analysis of all firefighters, adjusted for age, race and calendar year - but not socio-economic group, in this case - showed an excess of cancer cases in firefighters for oesophagus, lung (small cell-cancer), melanoma, prostate, kidney, brain, myeloma and acute myeloid leukaemia (Table 3); confusingly results are shown for the control cancers too, leading to doubts about the true design. The sites with excess are similar to those identified in the earlier Californian study, but there was now no excess for testicular cancer. Further analysis suggested some differences in firefighter risks between other races (365 cases) and white firefighters. However, since the registry does not have information on smoking, alcohol consumption and obesity, there is the same potential for confounding by these factors as in many other studies identified above, which could not be suitably compensated in the analysis.

All three of the studies so far in this section suffer from the fact that they are limited to a simple occupational classification with no information on exposures or workplace duties. Other case-control studies based on cancer site such as the one from Bigert et al. (2016) explore occupation and other factors in far more details, but in the end, are less robust for providing data for this review, due to the small number of firefighters included.

3.3 Conclusions from all studies in firefighters

Although a previous review by (IARC, 2010aa) could not reach a conclusion on the risk of specific cancers to firefighters several cancers were seen frequently in the studies reviewed. These were used to guide the current review and were the basis of selecting cancer sites for special consideration in the literature search. Any new evidence for excess cancer risk for firefighters at these sites is considered in detail in section 4 of this report.

In the current review, cancers were found at several of the sites previously noted but none were found consistently in all the studies reviewed. A deficiency in these studies, which has also been commented on by previous reviews, is the lack of good quality exposure data. There are five studies that rank more highly, mainly due to their longer duration and these show some consistency in identifying lung cancer, leukaemia, mesothelioma, kidney cancer and NHL as associated with the occupation of firefighter (Ahn et al., 2012; Daniels et al., 2014; Pukkala et al., 2014; Daniels et al., 2015; Glass et al., 2016).

Table 2: Summary of findings of cohort studies of cancer in firefighters

No.	Reference, location, name of study	Cohort description and reference group	Exposure categories	No. of cases/deaths	Rate ratio	Adjustment for potential confounders	Comments
				1950-2009 Mortality	**SMR (95% CI)**		
1	**USA** Pooled cohort of firefighters from San Francisco, Chicago and Philadelphia **(Daniels et al., 2014)** **Ranking of study:** **Selection** ★★ **Comparability** ★★ **Outcome** ★★★ **Exposure** ★★	29,993 firefighters employed for at least 1 day between 1950 and 2009 (4.4% were employed for < 1 year). Expected numbers of deaths and cancers were estimated from general US mortality rates (1950-2009). Additional mortality rates, limited to the period after 1959, were used for the estimates of expected cancer rates of small intestine, large intestine and testes. Mortality data was from National Death Index. In 2009, > 40% of the cohort was deceased and cause of death data was available for 99% of deaths. Cancer data was obtained from the relevant State cancer registries.	**All Firefighters**	**All cancers (3,285)**	**1.14 (1.10-1.18)**	Adjusted for gender, race, age and calendar year	Some additional analyses investigated the effect of sex, race, short-term vs. long-term employment on the outcome. These analyses showed no significant change in the overall mortality or cancer ratios. The only surrogate of exposure used in this cohort was duration of employment. This was only applied to selected end-points. The rate ratios are shown for all cancers of interest apart from the analysis by employment duration where only those showing significant differences are reported.
				Bladder (84)	0.99 (0.79-1.22)		
				Breast (8)	1.39 (0.60-2.73)		
				Brain (73)	1.01 (0.79-1.27)		
				Buccal & Pharynx (94)	**1.40 (1.13-1.72)**		
				Intestine (326)	**1.30 (1.16-1.44)**		
				Kidney (94)	**1.29 (1.05-1.58)**		
				Large intestine (264)	**1.31 (1.16-1.48)**		
				Leukaemia (122)	1.10 (0.91-1.31)		
				Lung (1046)	**1.10 (1.04-1.17)**		
				Mesothelioma (12)	**2.00 (1.03-3.49)**		
				Multiple myeloma (42)	0.89 (0.64-1.20)		
				NHL (123)	1.17 (0.97-1.40)		
				Oesophagus (113)	**1.39 (1.14-1.67)**		
				Prostate (282)	1.09 (0.96-1.22)		
				Rectum (89)	**1.45 (1.16-1.78)**		
				Stomach (110)	1.10 (0.91-1.33)		
				Testes (<5)	0.73 (0.15-2.14)		
				1985-2009 Cancer Incidence	**SIR (95% CI)**		
				All cancers - first cancer only (3,890)			
				Bladder (272)	**1.18 (1.05-1.33)**		
				Brain (48)	1.06 (0.78-1.41)		
				Breast (24)	1.32 (0.84-1.96)		
				Buccal & Pharynx (148)	**1.41 (1.20-1.66)**		
				Intestine (351)	**1.29 (1.16-1.43)**		
				Kidney (129)	**1.24 (1.04-1.48)**		
				Large intestine (335)	**1.28 (1.15-1.43)**		
				Leukaemia (85)	0.93 (0.83-1.16)		
				Lung (602)	**1.13 (1.04-1.22)**		
				Mesothelioma (26)	**2.00 (1.31-2.93)**		
				Multiple myeloma (33)	0.75 (0.52-1.06)		
				NHL (145)	0.99 (0.83-1.16)		
				Oesophagus (80)	**1.09 (1.06-1.12)**		
				Prostate (1176)	1.03 (0.97-1.09)		
				Rectum (140)	1.09 (0.91-1.28)		
				Stomach (72)	1.02 (0.80-1.28)		
				Testes (15)	0.79 (0.44-1.30)		

Table 2: Summary of findings of cohort studies of cancer in firefighters

No.	Reference, location, name of study	Cohort description and reference group	Exposure categories	No. of cases/deaths	Rate ratio	Adjustment for potential confounders	Comments
			(10-year lag)				
				Mortality	**SMR (95% CI)**		
				Oesophagus			
			Employed <10 yrs.	13	1.17 (0.62-2.00)		
			Employed 10 - <20 yrs.	**28**	**1.72 (1.14-2.48)**		
			Employed 20 - <30 yrs.	**53**	**1.40 (1.05-1.83)**		
			Employed 30+ yrs.	19	1.18 (0.71-1.84)		
				Stomach			
			Employed <10 yrs.	12	0.80 (0.41-1.40)		
			Employed 10 - <20 yrs.	18	0.92 (0.54-1.45)		
			Employed 20 - <30 yrs.	47	1.07 (0.79-1.43)		
			Employed 30+ yrs.	**33**	**1.53 (1.06-2.15)**		
				Intestine			
			Employed <10 yrs.	27	0.86 (0.57-1.26)		
			Employed 10 - <20 yrs.	52	1.27 (0.95-1.67)		
			Employed 20 - <30 yrs.	**171**	**1.42 (1.22-1.65)**		
			Employed 30+ yrs.	**76**	**1.28 (1.01-1.60)**		
				NHL			
			Employed <10 yrs.	18	0.98 (0.58-1.55)		
			Employed 10 - <20 yrs.	9	0.51 (0.23-0.96)		
			Employed 20 - <30 yrs.	**63**	**1.35 (1.04-1.73)**		
	Supplementary On-line data (Daniels et al., 2014a) Investigated the cancer rates separately in the three States included in the study	Using State mortality rates for comparison.	**Employed 30+ yrs.**	**33**	**1.47 (1.01-2.06)**		
					SMR (95% CI)		
			All Departments				
				Bladder (84)	0.94 (0.76-1.17)		
				Brain (73)	1.05 (0.83-1.32)		
				Intestine (326)	**1.19 (1.07-1.33)**		
				Kidney (94)	1.24 (0.96-1.61)		
				Leukaemia (122)	1.07 (0.90-1.28)		
				Lung (1046)	1.06 (0.92-1.23)		
				Multiple myeloma (42)	0.91 (0.67-1.23)		
				NHL (123)	1.11 (0.93-1.33)		
				Oesophagus (113)	**1.28 (1.06-1.54)**		
				Prostate (282)	1.04 (0.86-1.26)		
				Rectum (89)	**1.30 (1.01-1.68)**		
				Stomach (110)	1.05 (0.87-1.26)		
			San Francisco	Bladder (16)	0.91 (0.52-1.47)		
				Brain (16)	1.13 (0.64-1.83)		
				Intestine (56)	1.22 (0.92-1.59)		
				Kidney (13)	0.97 (0.51-1.66)		

Table 2: Summary of findings of cohort studies of cancer in firefighters

No.	Reference, location, name of study	Cohort description and reference group	Exposure categories	No. of cases/deaths	Rate ratio	Adjustment for potential confounders	Comments
		Compared with Californian rates.		Leukaemia (23)	1.07 (0.68-1.60)		
				Lung (142)	0.87 (0.73-1.02)		
				Multiple myeloma (7)	0.91 (0.52-1.47)		
				NHL (25)	1.17 (0.76-1.73)		
				Oesophagus (23)	**1.57 (1.00-2.36)**		
				Prostate (51)	0.90 (0.67-1.19)		
				Rectum (20)	**1.67 (1.02-2.59)**		
				Stomach (25)	1.20 (0.78-1.77)		
			Chicago	Bladder (40)	0.98 (0.70-1.33)		
				Brain (34)	1.01 (0.70-1.42)		
				Intestine (157)	**1.17 (1.00-1.37)**		
				Kidney (56)	**1.51 (1.14-1.96)**		
		Compared with Illinois rates.		Leukaemia (61)	1.10 (0.84-1.42)		
				Lung (566)	**1.20 (1.10-1.30)**		
				Multiple myeloma (19)	0.86 (0.52-1.34)		
				NHL (53)	0.99 (0.74-1.30)		
				Oesophagus (58)	**1.32 (1.00-1.71)**		
				Prostate (152)	**1.26 (1.07-1.48)**		
				Rectum (47)	**1.45 (1.07-1.93)**		
				Stomach (53)	1.10 (0.82-1.43)		
			Philadelphia	Bladder (28)	0.92 (0.61-1.33)		
				Brain (23)	1.05 (0.66-1.57)		
				Intestine (113)	1.19 (0.98-1.44)		
				Kidney (25)	1.06 (0.68-1.56)		
		Compared with Pennsylvania rates.		Leukaemia (38)	1.03 (0.73-1.41)		
				Lung (338)	1.10 (0.99-1.22)		
				Multiple myeloma (16)	1.07 (0.61-1.74)		
				NHL (45)	1.25 (0.91-1.68)		
				Oesophagus (32)	1.07 (0.73-1.52)		
				Prostate (79)	0.92 (0.73-1.15)		
				Rectum (22)	0.92 (0.58-1.40)		
				Stomach (32)	0.90 (0.61-1.27)		
2	**USA** Pooled cohort of firefighters from San Francisco, Chicago and Philadelphia **(Daniels et al., 2015)** and on-line	19,309 male firefighters employed since 1950 and followed through 2009. (Eligibility from the previous study cohort was restricted	NB: Exposure lag for NHL and leukaemia was 5 years and for all others was 10 years.	**Mortality**	**HR (95% CI)**	Adjusted for race, fire department and birth cohort.	No data available on lifestyle parameters such as smoking and alcohol consumption. The analysis was only applied to all cancers, colorectal, bladder, oesophageal, lung,
				Lung			
			Exposed days	429	0.93 (0.86-1.03)		
			Fire-runs	398	1.11 (0.95-1.29)		
			Fire-hours	**288**	**1.39 (1.12-1.73)**		

Table 2: Summary of findings of cohort studies of cancer in firefighters

No.	Reference, location, name of study	Cohort description and reference group	Exposure categories	No. of cases/deaths	Rate ratio	Adjustment for potential confounders	Comments
	supplementary data	to males of known	Exposed days	**Leukaemia**			and prostate cancer,
	(Daniels et al., 2015a)	race first hired on or	**Fire-runs**	52	1.38 (0.75-2.64)		plus NHL and
		after 1st January	**Fire-hours**	**45**	**1.45 (1.00-2.35)**		leukaemia
	Ranking of study:	1950 and further		**31**	**1.32 (0.87-2.36)**		
		limited to firefighters	Exposed days	**NHL**			Only analyses where
	Selection ★★	employed for one or	Fire-runs	53	1.30 (0.93-2.06)		the HR for any
	Comparability ★★★	more years.)	Fire-hours	47	0.70 (0.42-1.10)		analysis was > 1 are
	Outcome ★★★			29	0.54 (NC-1.08)		shown in the table
	Exposure ★★	Analysis is based on	Exposed days	**Oesophagus**			(NC = Not calculable).
		an internal	Fire-runs	61	0.61 (NC-1.10)		
		comparison within	Fire-hours	54	1.24 (0.91-1.88)		
		the cohort based		34	1.18 (0.80-1.98)		
		upon exposure.					
		Each case was		**Cancer Incidence**			
		matched with 200					
		controls based on	Exposed days	**All cancers**			
		attained age.	Fire-runs	2609	0.96 (0.87-1.05)		
			Fire-hours	2197	1.01 (0.95-1.08)		
				1395	1.01 (0.92-1.12)		
			Exposed days	**Bladder**			
			Fire-runs	174	1.01 (0.89-1.19)		
			Fire-hours	144	1.05 (0.89-1.27)		
				95	0.98 (0.79-1.27)		
			Exposed days	**Leukaemia**			
			Fire-runs	58	0.99 (0.56-1.89)		
			Fire-hours	49	1.08 (0.75-1.84)		
				33	0.90 (0.68-1.30)		
			Exposed days	**Lung**			
			Fire-runs	382	1.05 (0.84-1.33)		
			Fire-hours	358	1.10 (0.94-1.28)		
				243	**1.39 (1.10-1.74)**		
			Exposed days	**NHL**			
			Fire-runs	92	1.07 (0.92-1.28)		
			Fire-hours	79	0.79 (0.64-1.10)		
				45	1.12 (0.89-1.50)		
			Exposed days	**Oesophagus**			
			Fire-runs	54	0.66 (0.42-1.18)		
			Fire-hours	48	1.22 (0.89-1.88)		
				29	0.57 (NC-1.85)		
			Exposed days	**Prostate**			
			Fire-runs	832	0.90 (0.77-1.05)		
			Fire-hours	678	1.02 (0.91-1.14)		
				419	0.98 (0.90-1.09)		
3	**Nordic Countries**				**SIR (95% CI)**		No specific

Table 2: Summary of findings of cohort studies of cancer in firefighters

No.	Reference, location, name of study	Cohort description and reference group	Exposure categories	No. of cases/deaths	Rate ratio	Adjustment for potential confounders	Comments
	45-year follow-up of firefighters **(Pukkala et al., 2014)** **Ranking of study:** **Selection** ★★ **Comparability** ★★ **Outcome** ★★★ **Exposure** 0	16,422 male firefighters identified by census entry: 1943-2003 (Denmark) 760 firefighters; 1953-2003 (Norway) 2579 firefighters 1953-2004 (Finland) 4740 firefighters; 1955-2004 (Iceland) 199 firefighters; 1958-2005 (Sweden) 8144 firefighters. Mortality data was derived from the central population register. Cancer data was derived from national cancer registries Cancer rates in the entire national male population of each country were used as the reference rates.	**All firefighters**	**Total cancer cases (2,536)**	**1.06 (1.02-1.11)**	Results are adjusted for country, calendar period and age group.	adjustments are described for lifestyle although survey evidence is cited that smoking is less common in firefighters than in the general population while alcohol consumption is slightly higher. Non-melanoma skin cancers are excluded from all cancers, due to ambiguities in the Danish data. Only analyses where the SIR for any analysis was > 1 are shown in the table
				Bladder (194)	1.11 (0.96-1.28)		
				Brain	0.86 (0.66-1.10)		
				Colon (198)	1.14 (0.99-1.31)		
				Larynx (31)	1.06 (0.72-1.50)		
				Leukaemia -acute myeloid (21)	1.27 (0.79-1.94)		
				Lung adenocarcinoma (80)	**1.29 (1.02-1.60)**		
				Mesothelioma (17)	1.55 (0.90-2.48)		
				Multiple myeloma (41)	1.13 (0.81-1.53)		
				NHL (82)	1.04 (0.83-1.29)		
				Pancreas (87)	1.17 (0.94-1.45)		
				Pharynx (19)	1.00 (0.60-1.57)		
				Prostate (660)	**1.13 (1.05-1.22)**		
				Skin melanoma (109)	**1.25 (1.03-1.51)**		
				Skin - non-melanoma (117)	**1.33 (1.10-1.59)**		
				Small intestine (13)	1.15 (0.61-1.97)		
				Stomach (128)	1.09 (0.91-1.30)		
				Testis (9)	0.51 (1.23-0.98)		
				Thyroid (17)	1.28 (0.75-2.05)		
			Age at follow-up				
			30-49 yrs.	Mesothelioma (1)	1.02 (0.03-5.69)		
				Prostate (12)	**2.59 (1.34-4.52)**		
				Skin melanoma (37)	**1.62 (1.14-2.23)**		
			50-69 yrs.	**Prostate (309)**	**1.16 (1.04-1.30)**		
			70+ yrs.	**Total cancer (1071)**	**1.14 (1.07-1.21)**		
				Lung (141)	**1.28 (1.08-1.52)**		
				Lung adenocarcinoma (37)	**1.90 (1.34-2.62)**		
				Mesothelioma (10)	**2.59 (1.24-4.77)**		
				Multiple myeloma (24)	**1.69 (1.08-2.51)**		
				NHL (33)	1.30 (0.89-1.83)		
				Prostate (339)	1.09 (0.98-1.21)		
				Skin - non-melanoma (75)	**1.40 (1.10-1.76)**		
4	**Scotland** 20-year summary of cancer rates in Scottish	Approximately 2,200 firefighters	**All firefighters**	38 cancer cases	**Incidence rate/10^5/year (SD)**	Analysis derives incidence rates using serving	Data were available on smoking and drinking for > 95% of

Table 2: Summary of findings of cohort studies of cancer in firefighters

No.	Reference, location, name of study	Cohort description and reference group	Exposure categories	No. of cases/deaths	Rate ratio	Adjustment for potential confounders	Comments
	firefighters (1984-2005). **(Ide, 2014)** **Ranking of study:** **Selection** ★ **Comparability** ★ **Outcome** ★ **Exposure 0**	Cancer cases were obtained from the NHS Scotland. The reference population was men 20-54 from Scotland and the West of Scotland		**Kidney** Firefighters (4) West Scotland Scotland **Melanoma** Firefighters (6) West Scotland Scotland	 9.1 (18.7) 4.4 (1.2) 9.1 (1.2) 13.6 (21.4) 7.7 (2.3) 8.1 (1.8)	population as denominator; compares with the incidence rate for 20-54 year old in the reference population, but no clear description of the statistical methods used.	the cohort and on pre-fire-service jobs for around 50%. Numbers of each cancer type are too low for any valid analysis
5	**France** French Firefighter Mortality over 30 years. C.PRIM cohort **(Amadeo et al., 2015)** **Ranking of study:** **Selection** ★★ **Comparability** ★★ **Outcome** ★★★ **Exposure 0**	All professional male firefighters employed on January 1st 1979. followed until 31st December 2008. The final cohort was 10,829. Comparison was with the French male general population.	**All firefighters**	 All neoplasms (749) Bronchus and lung (217) Bladder (15) Colon (29) Kidney (10) Larynx and trachea (28) Lip, oral and pharynx (69) Liver (46) Lymph/ haematopoietic (42) Oesophagus (40) Pancreas (42) Prostate (17) Rectum and anus (23) Skin (5) Stomach (29)	**SMR (95% CI)** 0.95 (0.88-1.02) 0.86 (0.74-0.99) 0.73 (0.41-1.21) 0.73 (0.44-1.04) 0.63 (0.30-1.16) 1.10 (0.73-1.59) 1.15 (0.89-1.46) 1.10 (0.73-1.59) 0.89 (0.64-1.20) 0.93 (0.67-1.27) 1.27 (0.92-1.72) 0.54 (0.31-0.86) 1.36 (0.86-2.04) 0.65 (0.21-1.51) 1.15 (0.77-1.65)	Adjusted for age and calendar year	The mortality rate in the cohort was lower than in the comparator population, suggesting that a more relevant comparator than the general population may be appropriate. None of the individual cancers showed a significant increase compared with the general population.
6	**Australia** Male paid firefighters from eight of ten state fire agencies **(Glass et al., 2016)**	17,394 full-time and 12,663 part-time firefighters employed between 1980 and 2010. Cancer rates and mortality of whole	**All firefighters**	 **All cancer (1,208)** Bladder (28) Brain (28) Breast–male (6) Colorectal (214) Lip, oral cavity, pharynx (76) Kidney (52)	**SIR (95% CI)** **1.09 (1.03-1.14)** 0.78 (0.52-1.13) 0.93 (0.62-1.35) 2.17 (0.80-4.72) 1.08 (0.94-1.23) 0.93 (0.73-1.16) 1.08 (0.81-1.41)	Adjusted for age and sex and calendar year. There is no adjustment for ethnicity, smoking, alcohol	The rate ratios for all firefighters are reported here. Separate analysis was made for part-time and full -time firefighters but there was no difference in

Table 2: Summary of findings of cohort studies of cancer in firefighters

No.	Reference, location, name of study	Cohort description and reference group	Exposure categories	No. of cases/deaths	Rate ratio	Adjustment for potential confounders	Comments
	Ranking of study: **Selection** ★★ **Comparability** ★ **Outcome** ★★★ **Exposure** ★★	cohort compared with the rates for the general Australian population.		Leukaemia (43) Lung (101) Mesothelioma (15) Myeloma (18) **Male reproductive (357)** NHL (66) Oesophagus (17) Pancreas (29) **Prostate (325)** **Skin-melanoma (209)** Stomach (33) Testis (43) Thyroid (20)	1.00 (0.73-1.35) 0.71 (0.58-0.86) 1.34 (0.75-2.21) 1.00 (0.59-1.58) **1.26 (1.15-1.37)** 0.97 (0.75-1.24) 0.78 (0.46-1.26) 1.03 (0.69-1.48) **1.31 (1.19-1.43)** **1.44 (1.28-1.62)** 0.99 (0.68-1.39) 1.25 (0.91-1.69) 1.20 (0.74-1.86)	consumption, diet or other potential exposures as data were not available.	the sites showing a significant excess of cancer. †Comparison with the group employed for < 10 years. Analysis included all sites of cancer seen above but only those shown had any evidence of significantly higher rate ratios related to increased duration of employment.
		Internal comparisons using duration of employment	**Full-time firefighters†**		**RIR (95% CI)**		
			10-20 years	**Urinary tract (12)** Kidney (7) **Lympho-haematopoietic (22)** NHL (31)	**5.63 (1.25-25.30)** 6.95 (0.85-56.81) **2.38 (1.08-5.26)** 2.12 (0.71-6.34)		Firefighters were divided into tertiles based on the cumulative numbers of incidents attended per person-year, for each of the five incident categories (all incidents, all fire incidents, structural fires, landscape fires, vehicle fires).
			20+ years	**Urinary tract (45)** **Kidney (25)** **Lympho-haematopoietic (75)** **NHL (31)**	**5.92 (1.33-23.30)** **8.19 (1.01-66.62)** **3.08 (2.32-7.20)** **3.67 (1.28-10.54)**		
				Male reproductive cancer			
		Internal comparisons using incident data: 12.043 full-time and 7,681 part-time firefighters included. Comparison of two upper tertiles with the lowest tertile of exposure group	**All fire incidents** Tertile 2 Tertile 3 **Structural fires** Tertile 2 Tertile 3 **Vehicle fires** Tertile 2 Tertile 3	 (26) (66) (27) (65) (30) (63)	 **2.14 (1.24-3.70)** **1.96 (1.17-3.27)** 1.41 (0.81-2.47) **1.96 (1.21-3.17)** **1.80 (1.03-3.13)** **2.13 (1.31-3.48)**		
				Prostate cancer			
			All fire incidents Tertile 2 Tertile 3	 (20) (62)	 1.78 (0.91-3.48) **2.55 (1.45-4.50)**		

Table 2: Summary of findings of cohort studies of cancer in firefighters

No.	Reference, location, name of study	Cohort description and reference group	Exposure categories	No. of cases/deaths	Rate ratio	Adjustment for potential confounders	Comments
			Structural fires				
			Tertile 2	(20)	1.57 (0.81-3.04)		
			Tertile 3	(61)	**2.45 (1.40-4.26)**		
			Vehicle fires				
			Tertile 2	(22)	**1.95 (1.02-3.73)**		
			Tertile 3	(59)	**2.60 (1.50-4.54)**		
7	**ROK** Emergency responders study **(Ahn et al., 2012)** **Ranking of study:** **Selection** ★★ **Comparability** ★★★★ **Outcome** ★★ **Exposure** **0**	33,416 male Emergency Responders – alive on 31/12/1995 and employed for at least 1 month between 1st Jan 1980 31st Dec December 2007. Firefighters constituted 88.1% of the cohort and included all first-line firefighters, (pump, ladder, and operation chiefs), and second-line fire-fighters (drivers and division chiefs), but these were not separately assessed. Firefighters compared with the general population and with other emergency responders. Cancer data were obtained from the Korea National Cancer Center (KNCC)	**Firefighters (compared with general population)**		**SIR (95% CI)**	Adjusted for age and calendar year.	Data were obtained by questionnaire on smoking, alcohol and exercise but the analysis was not adjusted for these confounding factors. From 1996 to 2007, the number of cancers and number of all deaths were 486 (1.5% of the cohort) and 448 (1.3% of the cohort, including 157 cancer deaths), respectively. There was no follow-up loss. This cohort, with a high proportion of active workers, revealed a large healthy worker effect on cancer morbidity. †CI recalculated as value reported in paper was incorrect. The recalculation changed the significance of the result. Values for NHL and colorectal cancer may
			<10 years	All cancer (122)	1.00 (0.83-1.19)		
				Bladder (1)	0.39 (0.01-2.18)		
				Brain (2)	0.74 (0.08-2.66)		
				Colon and rectum (20)	1.35 (0.82-2.08)		
				Kidney (6)	1.62 (0.59-3.52)		
				Leukaemia (7)	1.60 (0.64-3.31)		
				Lung and bronchus (7)	0.69 (0.28-1.43)		
				NHL (6)	1.68 (0.62-3.67)		
				Pancreas (4)	1.80 (0.49-4.62)		
				Prostate (1)	0.75 (0.01-4.16)		
				Stomach (29)	0.98 (0.66-1.41)		
				Small intestine (1)	1.81 (0.02-10.09)		
				Thyroid (9)	1.21 (0.55-2.29)		
			≥10 years	All cancer (324)	0.96 (0.86-1.07		
				Bladder (16)	**1.98 (1.13-3.22)**		
				Brain (2)	0.42 (0.05-1.51)		
				Colon and rectum (52)	1.25 (0.95-1.63)		
				Kidney (14)	1.54 (0.84-2.58)		
				Leukaemia (6)	0.75 (0.27-1.62)		
				Lung and bronchus (29)	0.81 (0.54-1.16)		
				NHL (12)	1.69 (0.87-2.96)		
				Oesophagus (6)	0.94 (0.34-2.05)		
				Pancreas (5)			
				Prostate (8)	1.47 (0.63-2.89)		
				Stomach (77)	0.92 (0.72-1.14)		
				Small intestine (4)	2.71 (0.73-6.93)		
				Thyroid (10)	0.86 (0.41-1.59)		
			Total	All cancer (446)	0.97 (0.88-1.06)		
				Bladder (17)	1.60 (0.93-2.56)†		
				Brain (4)	0.53 (0.14-1.36)		
				Colon & Rectum (72)	**1.27 (1.01-1.59)**		
				Kidney (20)	1.56 (0.95-2.41) †		

Table 2: Summary of findings of cohort studies of cancer in firefighters

No.	Reference, location, name of study	Cohort description and reference group	Exposure categories	No. of cases/deaths	Rate ratio	Adjustment for potential confounders	Comments
				Leukaemia (13)	1.05 (0.56-1.79)		also be incorrect but the significance will not change.
				Lung and bronchus (36)	0.78 (0.55-1.09)		
				Oesophagus (6)	0.75 (0.28-1.64)		
				Pancreas (9)	0.95 (0.44-1.81)		
				Prostate (9)	1.32 (0.60-2.51)		
				NHL (18)	**1.69 (1.01-2.67)**		
				Stomach (106)	0.93 (0.76-1.13)		
				Small intestine (5)	2.46 (0.79-5.75)		
				Thyroid (19)	1.00 (0.60-1.56)		
					SRR (95% CI)		
			Firefighters (compared with non-firefighters)	All cancer (446)	0.83 (0.59-1.16)		
				Bladder (17)	0.40 (0.12-1.40)		
				Brain (4)	--		
				Colon & Rectum (72)	0.55 (0.26-1.19)		
				Kidney (20)	0.69 (0.16-2.99)		
				Leukaemia (13)	1.68 (0.22-13.06)		
				Lung and bronchus (36)	0.69 (0.21-2.26)		
				Oesophagus (6)	--		
				Pancreas (9)	0.58 (0.07-4.58)		
				Prostate (9)	0.22 (0.05-1.05)		
				NHL (18)	0.52 (0.15-1.78)		
				Stomach (106)	1.09 (0.53-2.25)		
				Small intestine (5)	--		
				Thyroid (19)	2.17 (0.29-16.51)		
8	**ROK** Emergency responders study **(Ahn and Jeong, 2015)** **Ranking of study:** **Selection** ★★ **Comparability** ★★★★ **Outcome** ★★ **Exposure** ★★	As above, but cohort said to be 33,442 workers. Study is reporting only mortality data (444 deaths from all causes among firefighters of which 167 were due to cancer)	**Firefighters**		**SMR (95% CI)**	As above	As above. The small number of cancer deaths limits the power of this study.
			Total	All cancers (167)	0.58 (0.50-0.68)		
				Colorectal (12)	0.65 (0.34-1.14)		
				Leukaemia (6)	0.66 (0.24-1.44)		
				Liver & Bile duct (50)	0.55 (0.41-0.73)		
				Lung & bronchus (26)	0.58 (0.38-0.84)		
				Lymphohaematopoietic cancer (15)	0.91 (0.51-1.50)		
				Stomach (34)	0.63 (0.43-0.88)		
			<10 yrs	All cancers (43)	0.66 (0.48-0.89)		
				Colorectal (2)	0.65 (0.34-1.14)		
				Leukaemia (1)	0.33 (0.00-1.86)		
				Liver & Bile duct (14)	0.69 (0.38-1.16)		
				Lung & bronchus (6)	0.69 (0.25-1.48)		
				Lymphohaematopoietic cancer (4)			
				Stomach (11)	0.80 (0.21-2.04)		

Table 2: Summary of findings of cohort studies of cancer in firefighters

No.	Reference, location, name of study	Cohort description and reference group	Exposure categories	No. of cases/deaths	Rate ratio	Adjustment for potential confounders	Comments
					0.89 (0.44-1.59)		
			≥10 yrs to <20 yrs.	All cancers (48)			
				Colorectal (5)	0.58 (0.50-0.67)		
				Leukaemia (3)	0.81 (0.26-1.90)		
				Liver & Bile duct (13)	0.83 (0.17-2.42)		
				Lung & Bronchus (7)	0.43 (0.23-0.73)		
				Lymphohaematopoietic cancer (6)	0.53 (0.21-1.10)		
				Stomach (9)	0.96 (0.35-2.08)		
					0.50 (0.23-0.95)		
			≥20 yrs.	All cancers (76)			
				Colorectal (5)	0.59 (0.47-0.74)		
				Leukaemia (2)	0.63 (0.20-1.48)		
				Liver & Bile duct (23)	0.81 (0.09-2.91)		
				Lymphohaematopoietic cancer (5)	0.58 (0.37-0.87)		
				Lung & Bronchus (13)	0.96 (0.31-2.23)		
				Stomach (14)	0.56 (0.30-0.96)		
					0.60 (0.33-1.00)		

Table 3: Summary of findings of registry-based case-control studies of cancer in firefighters

No.	Reference, location, name of study	Cases and controls; inclusion criterion for firefighter definition	Firefighters are (implicitly or explicitly) compared with	Cancer site (No. of cases/deaths)	Rate ratio	Adjustment for potential confounders	Comments
9					**SMOR (95% CI)**	Adjusted for age and smoking	When the analysis was conducted using three age-bands, the only significant result was for colon cancer in those aged 75+ with SMOR of 1.73 (1.06-2.84).
	USA Massachusetts firefighters **(Kang et al., 2008)** **Ranking of study:** **Selection** ★★ **Comparability** ★★ **Exposure** ★★	Cases and controls drawn from Mass. cancer registry, restricted to records 1987-2003 for white males aged 18+, with sufficient recorded job information. Cases: 24 'cancers of concern' based on literature review. Controls: all other cancers **Firefighters** identified as firema(e)n, firefighter, fire-lieutenant, fire-chief or fire-captain in "Usual Occupation" field on cancer registry 2125 cancers among firefighters	Police	Bladder (113)	1.22 (0.89-1.69)		
				Breast (4)	0.25 (0.03-2.31)		
				Brain (28)	**1.90 (1.10-3.26)**		
				Buccal cavity (21)	0.72 (0.37-1.41)		
				Colon (200)	**1.36 (1.04-1.79)**		
				Kidney (64)	1.34 (0.90-2.01)		
				Leukaemia (46)	0.72 (0.43-1.20)		
				Lung (379)	1.02 (0.79-1.31)		
				Multiple myeloma (29)	0.76 (0.39-1.48)		
				Nasopharynx (3)	1.17 (0.19-7.17)		
				NHL (13)	0.77 (0.31-1.92)		
				Oesophagus (57)	0.93 (0.61-1.41)		
				Pancreas (38)	0.86 (0.53-1.40)		
				Prostate (577)	0.98 (0.78-1.23)		
				Rectum (67)	0.86 (0.58-1.26)		
				Skin-melanoma (78)	0.65 (0.44-0.97)		
				Stomach (46)	0.83 (0.53-1.29)		
				Testes (25)	1.53 (0.75-3.14)		
				Thyroid (10)	0.71 (0.30-1.70)		
			All other occupations (excludes those with no recorded occupation).	Bladder (113)	1.19 (0.93-1.52)		
				Breast (4)	1.28 (0.47-3.47)		
				Brain (28)	1.36 (0.87-2.12)		
				Buccal cavity (21)	0.66 (0.41-1.06)		
				Colon (200)	1.15 (0.93-1.43)		
				Kidney (64)	1.01 (0.74-1.38)		
				Leukaemia (46)	0.98 (0.69-1.39)		
				Lung (379)	0.91 (0.76-1.10)		
				Multiple myeloma (29)	0.92 (0.58-1.47)		
				Nasopharynx (3)	1.31 (0.32-5.31)		
				NHL (13)	1.10 (0.58-2.09)		
				Oesophagus (57)	0.64 (0.47-0.87)		
				Pancreas (38)	0.84 (0.58-1.22)		
				Prostate (577)	1.05 (0.88-1.24)		
				Rectum (67)	1.03 (0.77-1.38)		
				Skin-melanoma (78)	1.04 (0.77-1.42)		
				Stomach (46)	0.97 (0.69-1.35)		
				Testes (25)	1.49 (0.88-2.48)		
				Thyroid (10)	0.81 (0.41-1.59)		

Table 3: Summary of findings of registry-based case-control studies of cancer in firefighters

No.	Reference, location, name of study	Cases and controls; inclusion criterion for firefighter definition	Firefighters are (implicitly or explicitly) compared with	Cancer site (No. of cases/deaths)	Rate ratio	Adjustment for potential confounders	Comments
10	**USA** California firefighters 1998-2004 **(Bates, 2007)** **Ranking of study:** **Selection** ★★ **Comparability** ★★★ **Exposure** ★★	Cases and controls drawn from California cancer registry, restricted to records 1988-2003 for males aged 18-80, with sufficient recorded job information. Cases: Cancers previously hypothesised to be linked to firefighting. **Controls 1**: all other cancers. **Controls 2**: other selected cancers. Firefighters identified using occupation field on cancer registry record. 3659 cancers among firefighters.	All other occupations (excludes those with no recorded occupation).		**OR (95% CI)**	Adjusted for race and socio-economic group.	The comparison with selected controls excluded cases with cancers of the lung and bronchus, bladder and prostate, colorectal cancers, and skin melanomas
				Bladder (174)			
				Controls 1	0.79 (0.68-0.92)		
				Controls 2	0.85 (0.72-1.00)		
				Brain (71)			
				Controls 1	1.23 (0.97-1.56)		
				Controls 2	**1.35 (1.06-1.72)**		
				Colorectal (282)			
				Controls 1	0.84 (0.74-0.94)		
				Controls 2	0.90 (0.79-1.03)		
				Kidney (101)			
				Controls 1	0.98 (0.81-1.20)		
				Controls 2	1.07 (0.87-1.31)		
				Leukaemia (100)			
				Controls 1	1.13 (0.92-1.37)		
				Controls 2	1.22 (0.99-1.49)		
				Lung & Bronchus (495)			
				Controls 1	0.92 (0.84-1.01)		
				Controls 2	0.98 (0.88-1.09)		
				Multiple myeloma (37)			
				Controls 1	0.97 (0.70-1.34)		
				Controls 2	1.03 (0.75-1.43)		
				NHL (159)			
				Controls 1	0.98 (0.84-1.15)		
				Controls 2	1.07 (0.90-1.26)		
				Oesophagus (62)			
				Controls 1	**1.37 (1.06-1.76)**		
				Controls 2	**1.48 (1.14-1.91)**		
				Pancreas (63)			
				Controls 1	0.85 (0.66-1.09)		
				Controls 2	0.90 (0.70-1.17)		
				Prostate (1,144)			
				Controls 1	**1.20 (1.12-1.29)**		
				Controls 2	**1.22 (1.12-1.33)**		
				Skin - melanoma (323)			
				Controls 1	**1.44 (1.28-1.62)**		
				Controls 2	**1.50 (1.33-1.70)**		
				Stomach (51)			
				Controls 1	0.77 (0.58-1.02)		
				Controls 2	0.80 (0.61-1.07)		

Table 3: Summary of findings of registry-based case-control studies of cancer in firefighters

No.	Reference, location, name of study	Cases and controls; inclusion criterion for firefighter definition	Firefighters are (implicitly or explicitly) compared with	Cancer site (No. of cases/deaths)	Rate ratio	Adjustment for potential confounders	Comments
				Testis (70) Controls 1 Controls 2 Thyroid (32) Controls 1 Controls 2	 **1.34 (1.04-1.74)** **1.54 (1.18-2.02)** 1.06 (0.75-1.51) 1.17 (0.82-1.67)		
11	**USA** California firefighters 1998-2007 **(Tsai et al., 2015)** **Ranking of study:** **Selection** ★★★★ **Comparability**★★ **Exposure** ★★	Cases and Controls drawn from California cancer registry, restricted to records 1988-2007 for males aged 21-97, with sufficient recorded job information. Cases: 32 cancers hypothesised as potentially linked to firefighting. Controls: 48725 cancers at four sites: pharynx, stomach, liver and pancreas - considered a priori not to be linked with firefighting. Firefighters identified using occupation field on cancer registry. 3,996 cancers in firefighters.	**All firefighters**	 Bladder (106) **Brain (87)** Colorectal (347) Gum & mouth (14) **Kidney (115)** Larynx (25) **Leukaemia (122)** Lung & Bronchus (533) **Lung (non-sp. small cell) (42)** **Melanoma (265)** **Multiple myeloma (55)** **NHL (183)** **Oesophagus (68)** Pancreas (79) Pharyngeal (43) **Prostate (1397)** Stomach (52) Testes (85) Thyroid (41) Tongue (4)	**OR (95% CI)** 0.99 (0.78-1.26) **1.54 (1.19-2.00)** 1.10 (0.93-1.31) 1.07 (0.62-1.85) **1.27 (1.01-1.59)** 0.59 (0.39-0.89) **1.32 (1.05-1.66)** 1.08 (0.92-1.28) **2.01 (1.38-2.93)** **1.75 (1.44-2.13)** **1.35 (1.00-1.82)** **1.22 (1.00-1.50)** **1.59 (1.20-2.09)** 1.10 (0.83-1.46) 1.06 (0.75-1.50) **1.45 (1.25-1.69)** 0.81 (0.59-1.11) 1.10 (0.73-1.66) 1.27 (0.88-1.84) 1.18 (0.82-1.70)	Adjusted for age at diagnosis, year of diagnosis and race.	Classification of target site used SEER classification not reported here.
12	**Multinational (Europe, Canada, New Zealand and China)** Synergy project **(Bigert et al., 2016)**	Pooled data on 14,748 cases of lung cancer and 17,543 controls from more than 14 studies with lifetime work histories and smoking habits for each individual.	Firefighters (190) are compared with non-firefighters (14,662 cases and 17,439 controls).	 Lung Cancer (86) Firefighter (190) Ever (86) <6 yrs. (32) 6-21 yrs. (22) 22-32 yrs. (14) ≥ 33 yrs. (18)	**OR (95% CI)** 0.95 (0.68-1.32) 1.21 (0.67-2.19) 0.97 (0.51-1.84) 0.69 (0.32-1.49) 0.92 (0.48-1.78)	The analysis reported adjusted for study, age, ever employment, cumulative cigarette smoking (pack years) and time since quitting.	Described in section 4.8.

Table 3: Summary of findings of registry-based case-control studies of cancer in firefighters

No.	Reference, location, name of study	Cases and controls; inclusion criterion for firefighter definition	Firefighters are (implicitly or explicitly) compared with	Cancer site (No. of cases/deaths)	Rate ratio	Adjustment for potential confounders	Comments
13	**Canada (British Colombia)** Colon cancer cases from British Colombia cancer registry **(Fang et al., 2011)**	1,155 cases of colon cancer recorded on British Columbia cancer registry between 1983 and 1990.	7,552 controls were cases recorded on the same registry with cancer at all other sites apart from lung, rectum and those of unknown primary origin.	Ever worked as firefighter (9) Main occupation firefighter (7)	**OR (95 % CI)** 1.50 (0.71-2.17) 1.83 (0.78-4.32)	Results adjusted for marital status; education; smoking; alcohol consumption; and person who filled out the questionnaire.	Occupation was determined by telephone interview Described in section 4.4.
14	**Europe (France)** ICARE study of head and neck cancer in France **(Paget-Bailly et al., 2013)**	1,833 cases of head and neck cancer including malignant neoplasms of lip, OC, pharynx, larynx, nasal cavity and accessory sinuses, diagnosed between 2001 and 2007.	2,747 controls selected from the general population of the same areas as the cancer registries frequency matched to cases by age, sex, and residence area	Ever employed as firefighter (13) ≤ 10 Years as a firefighter >10 years as a firefighter	**OR (95% CI)** **3.9 (1.4-11.2)** 0.5 (0.1-3.8) **7.6 (2.4-24.0)**	Smoking and alcohol consumption were considered in the analysis.	Described in section 4.5.
15	**Europe (Germany)** Laryngeal cancer in Germany **(Santi et al., 2013)**	208 male laryngeal cancer cases and 702 controls from 5 German cities.	Controls drawn randomly from the population of the relevant region				Firefighters are combined with cooks and waiters in the analysis. ORs not calculated for occupation. Described in section 4.5.
16	**USA** Detroit & Chicago renal cancer **(Karami et al., 2012)**	1,217 cases (77% of total cases recorded) diagnosed with renal cell carcinoma between 2002 and 2007. (Cases were identified differently in Detroit and Chicago).	1,235 controls drawn from general population; matched by age, sex and ethnicity with cases.	Ever employed (8) < 5 years (3) > 5 years (5)	**OR (95% CI)** 1.4 (0.4-4.7) 3.2 (1.0-8.8E+09) 1.1 (0.3-4.8)		Described in section 4.6.
17	**Europe** Seven city study of renal cancer **(Heck et al., 2010)**	992 cases of renal cell carcinoma diagnosed between 1999 and 2003	1,465 controls drawn from hospital patients without cancer.	Firefighters (<10)	No details given but stated not to be significant.		Described in section 4.6

Table 3: Summary of findings of registry-based case-control studies of cancer in firefighters

No.	Reference, location, name of study	Cases and controls; inclusion criterion for firefighter definition	Firefighters are (implicitly or explicitly) compared with	Cancer site (No. of cases/deaths)	Rate ratio	Adjustment for potential confounders	Comments
18	**New Zealand** Lung cancer case-control study **(Corbin et al., 2011)**	457 cases lung cancer notified to the New Zealand cancer registry during 2007-2008	792 population controls, recruited using the New Zealand electoral roll.	Firefighters 93)	**OR (95% CI)** † 1.2 (0.51-2.83)	Adjusted for gender, age, ethnicity, smoking and socio-economic status	Information obtained by personal telephone interview. †Semi-Bayes adjusted. Described in section 4.8.
19	**Europe (16 Centres)** Multi-centre study of PAH and lung cancer **(Olsson et al., 2010)**	All newly diagnosed lung cancer cases < 75 years of age between 1998 and 2002 in 16 centres in 7 countries. (2852).	Population controls were selected from the electronic register of residents in Warsaw and from the general practitioner registry in Liverpool. In the other centres, controls were selected from patients admitted to the same hospitals as the cases or from general hospitals serving the same population. excluding smoking-related conditions or other cancers (2923)	Firefighters Lung (5) (also 5 in control group)	Classified as exposed to PAH but no OR calculated.	Adjusted for age group, sex, study centre, tobacco pack-years, and occupational exposure (ever/never) to silica, asbestos and metals (arsenic, chromium [VI], cadmium).	Face-to-face interviews based on a structured questionnaire. PAH exposure calculated based on the occupational data. Study shows no association of lung cancer with PAH exposure. Described in section 4.8.
20	**Canada (Montreal)** Diesel and gasoline emissions and lung cancer **(Parent et al., 2007)**	857 male lung cancer patients among Montreal area residents between 1979 and 1985.	533 controls selected from the electoral list and 1,349 cancer patients identified in the same period and form the same area as the cases.	A team of chemists and industrial hygienists examined each completed questionnaire (blind to the disease status) and translated each job into a list of potential exposures by using a checklist that mentioned some 300 substances, including gasoline and diesel engine emissions	**OR (95% CI)** None of the exposures (diesel or gasoline emissions) gave significant results for lung cancer rates.	Age, family income, respondent status, ethnicity, smoking, and occupational exposure to asbestos and silica.	Interviewed face to face. Firefighters were classified as 94% exposed to medium level of gasoline and diesel emissions at a medium frequency. Described in section 4.8.
21	**Canada** Occupational exposure to diesel and gasoline emissions	1,681 cases of lung cancer > 40 years of age identified between 1994 and 1997.	2,053 controls were selected from the general population of 8 Canadian provinces, excluding Quebec	Firefighters Lung (22)	**OR (95% CI)** 1.70 (0.84-3.43)		The occupational information was assessed to judge exposure to diesel and gasoline emissions.

Table 3: Summary of findings of registry-based case-control studies of cancer in firefighters

No.	Reference, location, name of study	Cases and controls; inclusion criterion for firefighter definition	Firefighters are (implicitly or explicitly) compared with	Cancer site (No. of cases/deaths)	Rate ratio	Adjustment for potential confounders	Comments
	(Villeneuve et al., 2011)						Described in section 4.8.
22	**Canada** Occupational exposure to asbestos and lung cancer **(Villeneuve et al., 2012)**	1,681 lung cancer cases identified between 1994 and 1997.	Control group of 2,036 was drawn from the general population of eight provinces.	Ever exposed to asbestos. Lung (233)	**OR (95% CI)** **1.28 (1.02-1.61)**	Adjusted for age, province, cigarette pack years, occupational exposure to diesel and silica, exposure to second hand smoke.	Exposure to asbestos was based on responses to a mail questionnaire. Firefighters were classified as definitely exposed to asbestos at a low concentration with medium frequency. Described in section 4.8.
23	**Canada (British Colombia)** Occupational Cancer Risk in British Columbia - lung cancer **(MacArthur et al., 2009)**	2,988 cases of male lung cancer diagnosed between 1983 and 1990 based British Columbia cancer registry.	10,223 age-matched cancer controls from same registry. Only cancers of breast and reproductive organs excluded.	Protective services (SOC code 611) Lung (132)	**OR (95% CI)** **1.27 (1.05-1.55)**	Adjusted for tobacco smoking, alcohol consumption, marital status, educational attainment, and questionnaire respondent	Self-administered questionnaire including job descriptions, job duration, (full-time or part-time), marital status, ethnic origin, highest completed level of education, and respondent to the questionnaire Described in section 4.8.
24	**USA (Massachusetts)** Analysis of cancer registry data 1988–2003 **(Roelofs et al., 2013)**	564 cases of mesothelioma registered with the Massachusetts cancer registry between 1998 and 2003 with a record of occupation (40% of total cases over that period).	Compared to age-matched non-asbestos associated cancer cases (also excluding cases that had occupational history in an industry where asbestos exposure is known) from the same registry.	Pleura (mesothelioma) (19)	**SMOR (95% CI)** 2.2 (1.4-3.4)	Gender and age.	Described in section 4.9.

Table 3: Summary of findings of registry-based case-control studies of cancer in firefighters

No.	Reference, location, name of study	Cases and controls; inclusion criterion for firefighter definition	Firefighters are (implicitly or explicitly) compared with	Cancer site (No. of cases/deaths)	Rate ratio	Adjustment for potential confounders	Comments
25	**New Zealand** Case-control study of NHL and occupation **('t Mannetje et al., 2008)**	291 cases of NHL notified to the cancer registry in New Zealand during 2003-2004.	471 population controls randomly selected form the New Zealand electoral roll frequency matched by age to the NHL cases.	Since firefighters had < 10 cases there was no further analysis		Adjusted for gender, age and smoking status, ethnicity and occupation.	Face to face interviews established demographic information and full occupational history Described in section 4.11.

Note: The Newcastle-Ottawa assessment was not applied to studies which considered multiple occupations nor to the Bigert et al. (2016) paper which combined data from multiple studies and does not give sufficient information in the paper to assess the methodologies.

3.4 Publications and studies retrieved by the literature search but not used in the review

Reviews, meta-analyses and case-control studies, which report some association between cancer at specific sites and occupation, have been retrieved by the literature search conducted for this review. Where those studies do not identify the occupation of firefighter as associated with cancer they have been screened out of further consideration and are not mentioned in the review. All studies and reports which have been retrieved by the search but found not to be relevant are tabulated in Annex 4 to this report as rejected papers, with a brief summary and the reason for rejection.

3.4.1 Studies of 9/11 emergency responders

Within the literature retrieved there were several studies of emergency responders involved in the New York 9/11 responses (Zeig-Owens et al., 2011; Li et al., 2012; Solan et al., 2013; Zeig-Owens, 2015; Moir et al., 2016; Stein et al., 2016). These studies are uniquely related to the specific one-off exposures experienced on that occasion and have had only 15 years of follow-up. They were examined in detail and found to contain no information of relevance to cancer-risk in firefighters, so they are not considered further in this review.

4. OVERVIEW OF CANCER AT SPECIFIC SITES, WITH CONCLUSIONS REGARDING RELEVANCE TO FIREFIGHTERS

The only studies which are given attention in this section are those which contain data which relate to firefighters directly or to exposures which may be relevant to that occupation. This includes some other case-control studies not mentioned in section 3 but included in Table 3. These are studies which were not aimed directly at studying firefighters. Where exposures of firefighters have been identified to substances that may be relevant to cancer at a site then data on that association are included in the discussion.

Tables in this section show all results relevant to the cancer of concern from the studies reviewed. Significant results are highlighted in bold and those which are not significant but where the lower bound is > 0.95 are highlighted in bold but grey. The data refer to the studies reported more fully in Table 2 and Table 3.

The present review did not find sufficient evidence for a definitive conclusion of a positive association of any cancer type with the occupation of firefighter, apart from mesothelioma. Such evidence might be found if all available data were to be analysed by a meta-analysis; however, previous attempts suggest that it is unlikely. In consequence, the authors have attempted to categorise the data retrieved for the limited period of the review in such a way as to indicate the likelihood of association of each cancer type with occupation of firefighter. Inevitably this assessment has depended upon a rather subjective evaluation of the data. However, the use of consistent criteria is intended to optimise the outcome.

4.1 Bladder

Data on the relevant results for bladder cancer risk in the studies considered in section 1 is shown in Table 4 below. There was no evidence for an excess mortality rate from bladder cancer among firefighters from the two studies that reported such data. The results for bladder cancer incidence for firefighters in seven studies were somewhat variable increases in the rates and achieved significance in only one study (Daniels et al., 2014) (Study 1). From those studies, which considered more refined exposure categories, only one showed some evidence of a relationship in firefighters who had worked more than 10 years (Ahn et al., 2012) (Study 7).

Bladder cancer is known to be linked to tobacco smoking. Although most studies had no adjustment for smoking, the background information on smoking rates suggest that in general firefighters, if anything, smoke slightly less than the general population, the most frequent comparator, although each population may differ. The possibility of an effect independent of smoking cannot therefore be dismissed on that basis.

A meta-analysis on the association between bladder cancer and occupation was based upon 130 separate studies (66 cohort studies and 64 case-control studies) and gave results for 63 different occupations (Reulen et al., 2008). The occupation of firefighter was referenced in 9 of the included studies and showed no overall association with bladder cancer (SRR; 1.17 (0.92-1.49)).

Polycyclic aromatic hydrocarbon (PAH) exposure is suspected of being associated with bladder cancer (Kellen et al., 2007; Brown et al., 2012) and firefighters may have some potential for higher PAH exposures than the rest of the population. However, a study considering occupational exposure to PAH and bladder cancer showed no evidence of dose-relationship with bladder cancer incidence (Richardson et al., 2007).

Although an association between bladder cancer and the occupation of firefighter is seen in only two studies reviewed, the possibility of the association with occupation cannot be excluded.

The inconclusive and inconsistent evidence found in the current assessment is in line with an extensive review on this topic (Golka and Weistenhofer, 2008) and the conclusions of the previous IARC review (IARC, 2010a).

Conclusion

Based on the detection of an association in two studies, one with a dose-related trend, and a marginal effect in a third, it is considered that the occupation of firefighter may be associated with an increased risk of bladder cancer although the degree of statistical association is classified as **limited**. Since there is no strong evidence for a potential causative factor in firefighters' exposure and studies with more refined analysis and more appropriate comparator populations showed no associations the evidence is regarded as **weak**.

Table 4: Summary of data on bladder cancer in firefighters

	Mortality		Incidence	
Study number and Reference	**All firefighters (SMR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**	**All firefighters (SIR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**
1:(Daniels et al., 2014)	0.99 (0.79-1.22)[1]	<10 yrs. 1.05 (0.45-2.08)[2] 10-<20 Yrs. 0.65 (0.26-1.34)[2] 20-<30 Yrs. 1.08 (0.79-1.45)[2] >30 yrs. 0.94 (0.60-1.41)[2]	**1.18 (1.05-1.33)[3]**	—
2: (Daniels et al., 2015)	—	—	—	**RR for 75th vs 25th percentile** Exposed days 1.01 (0.89-1.19) Fire-runs 1.05 (0.89-1.27) Fire-hours 0.98
3: (Pukkala et al., 2014)	—	—	**1.11 (0.96-1.28)**	—
5: (Amadeo et al., 2015)	0.73 (0.41-1.21)	—	—	—
6: (Glass et al., 2016)	—	—	0.78 (0.52-1.13)	**RR for 3rd tertile vs 1st (Urinary Tract)** all incidents 0.99 (0.32-3.06) all fires 1.51 (0.47-4.86) all structural fires 1.00 (0.32-3.09) Vehicle fires 2.01 (0.66-6.46)
7: (Ahn et al., 2012)	—	—	1.60 (0.93-2.56)[4] 0.40 (0.12-1.40)[5,]	<10 yrs. 0.39 (0.01-2.18)[4] **≥10 yrs. 1.98 (1.13-3.22)[4]**
9: (Kang et al., 2008)	—	—	1.19 (0.93-1.52)[6] 1.22 (0.89-1.69)[7]	—
10: (Bates, 2007)	—	—	0.85 (0.72-1.00)	—
11: (Tsai et al., 2015)	—	—	0.99 (0.78-1.26)	—

— Analysis not part of objectives or not shown
Superscripts beside data indicate the following:
[1] compared to local state populations; [2] compared to US population; [3] restricted to 1st cancers; [4] compared to Korean population; [5] compared to other Emergency responders; [6] compared to all other occupation; [7] compared to police

4.2 Bone

Bone was included as a site with potential link to occupational cancer in firefighters.

From all of the evidence reviewed there was no mention of any association of bone cancer with the occupation of firefighter apart from a supplementary analysis by Daniels et al. (2014) where a SIR of 2.62 (1.35-4.57) was reported, based on < 13 cases.

4.3 Breast (in men)

One cohort study reported a small number of cases of male breast cancer with no significant difference from the control population in mortality or incidence (SMR 1.39 (0.60-2.73)) (SIR 1.32 (0.84-1.96)) (Daniels et al., 2014). Additionally, one case-control study reported on the incidence of male breast cancer in firefighters, identifying 4 cases (SMOR 0.25 (0.03-2.31)) in a comparison with the police as a reference group (Kang et al., 2008). A further case-control study, drawing on data from Denmark, France, Germany, Italy, Sweden, Latvia, Portugal and Spain compared 122 cases of male breast cancer with controls selected from similar populations to the cases for each nationality (Villeneuve et al., 2010). The controls were selected slightly differently in each country. Classification of the individual occupation was achieved by interview. A category of protective service workers (ISCO 5-8), which includes firefighters, but only as a minority group, was identified to have an OR for breast cancer of 1.7 (0.7-4.0), based on 6 cases.

Apart from these studies no other data have been identified from the current review, which might relate to an association of male breast cancer with the occupation of firefighter.

Conclusion

The data retrieved in this review provided no new evidence for an association between the occupation of firefighter and the risk of breast cancer in men.

4.4 Brain

Data on the relevant results for brain cancer risk in the studies considered in section 1 is shown in Table 5 below. Although brain cancer has been suggested as a cancer potentially associated with the occupation of firefighter (IARC, 2010a), previous reviews have not found enough data to fully confirm such an association (McGregor, 2005a; LeMasters et al., 2006). The cohort studies identified in this literature search did not show any association between the occupation of firefighter and brain cancer; however, the case-control studies showed a different picture. An association with the occupation of firefighter was reported for brain cancer when compared with police officers (Kang et al., 2008) (Study 9); a similar association was not present if the comparator group was all other occupations, but, as discussed in section 3.2, the police comparison is considered to be more relevant. A study of Californian cancer and occupation identified an excess of brain cancer in firefighters compared with the general population when cancers likely to be associated with firefighting were excluded from controls (Bates, 2007) (Study 10) . A case-control study of cancer rates in Californian firefighters compared with the general Californian population also identified an excess of brain cancers with the occupation of firefighter (Tsai et al., 2015) (Study 11). However, it is important to note that there is substantial overlap in the population bases for studies 10 and 11 - the latter includes cases from 1988-2007 and the former from 1988-2003 reported to the Californian cancer registry – although some aspects of the methodology differed. All three case-control studies are based on 'usual' occupation.

A systematic review of occupational and environmental risk factors of adult primary brain cancers concluded that firefighters may face an increased risk of brain cancer (Gomes et al., 2011), but the main evidence for an association came from two studies detailed above (Bates, 2007; Kang et al., 2008). A second review of occupational associations with brain cancer mentioned firefighters as a potentially associated occupation but did not report any results or conclusions to support that link (Brown et al., 2012).

Toxic exposures and brain cancer has been considered in a number of studies and exposure to heavy metals and epigenetic effects have been suggested as a possible mechanism (Caffo et al., 2014). Prolonged exposure to arsenic, lead, nickel and cadmium within smoke particulates, as might conceivably occur in firefighting, can generate reactive oxygen radicals, and cause DNA damage.

Conclusion

The association of brain cancer with the occupation of firefighter is classified as **mixed**, based on the approach used for this study, since three case-control studies showed a statistically significant association. The association in a study where firefighters were compared with police is considered quite strong evidence, since this constitutes an ideal comparison group and is supported by evidence from the two Californian case-control studies. Firefighters are also known to be exposed to substances which could be linked to brain cancer. However, since none of the cohort studies have confirmed this association the overall evidence from the new data is considered to be **weak**.

Table 5: Summary of data on brain cancer in firefighters

	Mortality		Incidence	
Study number and Reference	**All firefighters (SMR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**	**All firefighters (SIR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**
1:(Daniels et al., 2014)	1.01 (0.79-1.27)[2]	—	1.06 (0.78-1.41)[3]	—
3: (Pukkala et al., 2014)	—	—	0.86 (0.66-1.10)	—
6: (Glass et al., 2016)	—	—	0.93 (0.62-1.35)	—
7: (Ahn et al., 2012)	—	—	0.53 (0.14-1.36)[4]	< 10 yrs. 0.74 (0.08-2.66)[4] ≥ 10 yrs. 0.42 (0.05-1.51)[4]
9: (Kang et al., 2008)	—	—	**1.90 (1.10-3.26)**[7] 1.36 (0.87-2.12)[6]	—
10: (Bates, 2007)	—	—	**1.23 (0.97-1.56)**[8] **1.35 (1.06-1.72)**[9]	—
11: (Tsai et al., 2015)	—	—	**1.54 (1.19-2.00)**[6]	—

— Analysis not part of objectives or not shown
Superscripts beside data indicate the following:
[1] compared to local state populations; [2] compared to US population; [3] restricted to 1st cancers; [4] compared to Korean population; [5] compared to other Emergency responders; [6] compared to all other occupation; [7] compared to police; [8] compared to all other cancers; [9] compared to other selected cancers

4.5 Colorectal

Data on the relevant results for colorectal cancer risk in the studies considered in section 1 is shown in Table 6 below. One cohort study identified large intestine (colon/rectum and rectum alone) as a cancer site associated with excess mortality and cancer incidence in firefighters (Daniels et al., 2014) (Study 1). However, when the three separate fire service data were analysed separately for rectal cancer mortality only two showed a significant difference from the state population comparator, indicating that some factor, other than occupation, might be playing a part. A cohort study of Korean firefighters also showed an association of colon and rectum cancer with the occupation of firefighter when the comparison was made with the Korean population but there was no excess compared to “other emergency responders” (Ahn et al., 2012) (Study 7). Of the case-control studies, one study reported colon cancer rates that were higher in firefighters compared with police, and in those aged > 75Yrs (Kang et al., 2008) (Study 9).

Of the case-control studies of colorectal cancer retrieved in the current review only one reported firefighters as an occupation (Fang et al., 2011) (Study 13). In this study 1,156 colon cancer patients from British Colombia were compared with a control population of 7,552 derived from other cancer patients, excluding those with lung, rectum and unknown primary site. There were only seven cases with firefighters identified as their usual occupation and 9 who had at any time been a firefighter. There was no demonstration of an association between firefighting and colon cancer, although the small numbers involved are not really sufficient for any valid analysis.

A meta-analysis of the epidemiological evidence for an association between occupation and colorectal cancer identified no new data specific to firefighters and did not identify any association between the occupation of firefighter and colorectal cancer (Oddone et al., 2014).

There is little evidence of exposure of firefighters to substances known to be linked with colon cancer, but an association has been found with rectal cancer and exposure to metals in smoke particulates, such as arsenic, lead, cadmium, nickel and polychlorinated biphenyls and such exposures are possible in firefighting activities (Prince et al., 2006).

Conclusion

Since at least three studies showed a statistically significant association of occupation of firefighter with colorectal cancer, it is concluded that the degree of statistical association is **mixed**. This is reinforced by the knowledge that firefighters may be exposed to substances, such as polychlorinated biphenyls, which have been linked to rectal cancer. However, considering particularly the lack of any exposure-related association, in those studies where such evidence was obtained, the evidence for association from these new data is considered to be **very weak**.

Table 6: Summary of data on colorectal cancer in firefighters

	Mortality		Incidence	
Study number and Reference	**All firefighters (SMR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**	**All firefighters (SIR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**
1: (Daniels et al., 2014)	**Colon & rectum** **1.18 (1.08-1.28)**[2] **Rectum only** **1.45 (1.16-1.78)**[2]	**Rectum only)** **1.67 (1.02-2.59) (**San Francisco) **1.45 (1.07-1.93)** (Chicago) 0.92 (0.58-1.40) (Philadelphia)	**Large intestine** **1.28 (1.15-1.43)**[3] **Rectum** 1.09 (0.91-1.28)[3]	—
3: (Pukkala et al., 2014)	—	—	**Colon only** **1.14 (0.99-1.31)**	—
5: (Amadeo et al., 2015)	**Colon only** 0.73 (0.44-1.04) **Rectum & anus** 1.36 (0.86-2.04)	—	—	—
6: (Glass et al., 2016)	—	—	1.08 (0.94-1.23)	—
7: (Ahn et al., 2012)	—	—	**1.27 (1.00-1.59)**[4] 0.55 (0.26-1.19)[5]	< 10 Yrs. 1.35 (0.82-2.08)[4] ≥ 10 Yrs. 1.25 (0.95-1.63)[4]
8: (Ahn and Jeong, 2015)	0.65 (0.34-1.14)	< 10 yrs. 0.65 (0.34-1.14) 10-20 yrs. 0.81 (0.26-1.90) ≥ 20 yrs. 0.63 (0.20-1.48)	—	—
9: (Kang et al., 2008)	—	—	**Colon only** **1.36 (1.04-1.79)**[7] 1.15 (0.93-1.43)[6]	**Colon only** 18-54 yrs. 1.05 (0.55-1.99) 55-74 yrs. 1.24 (0.85-1.81) **≥75 yrs. 1.73 (1.06-2.84)**
10: (Bates, 2007)	—	—	0.84 (0.74-0.94)	—
11: (Tsai et al., 2015)	—	—	1.10 (0.93-1.31)[8] 0.90 (0.79-1.03)[9]	—
13: (Fang et al., 2011)	—	—	—	**Colon only** Ever Ff. 1.50 (0.71-2.17) Main Occ. 1.83 (0.78-4.32)

— Analysis not part of objectives or not shown; Ff = Firefighter
Superscripts beside data indicate the following:
[1] compared to local state populations; [2] compared to US population; [3] restricted to 1st cancers; [4] compared to Korean population; [5] compared to other Emergency responders; [6] compared to all other occupation; [7] compared to police; [8] compared to all other cancers; [9] compared to other selected cancers

4.6 Head & Neck (including larynx, pharynx and nasopharynx)

Data on the relevant results for head and neck cancer risk in the studies considered in section 1 is shown in Table 7 below. One of the cohort studies retrieved in this review identified an excess of buccal/pharyngeal cancer and deaths in firefighters in comparison with the general population (Daniels et al., 2014) (Study1). A subsequent analysis of data from a restricted sample of the same cohort using more refined exposure criteria did not select this cancer site for further investigation thus no further insight was gained (Daniels et al., 2015). An excess of tongue cancer was reported in one case-control study of firefighters (Tsai et al., 2015) (Study 11).

A French study of head and neck cancer (ICARE study) based on cancer registries, analysed 1,833 cases, including malignant neoplasms of lip, OC (oral cavity), pharynx, larynx, nasal cavity and accessory sinuses, diagnosed between 2001 and 2007 (Paget-Bailly et al., 2013) (Study 14). The incidence for a range of occupations was compared with that of 2,747 controls selected from the general population of the same areas as the cancer registries. Details of occupational history, smoking history and alcohol consumption was obtained by face-to-face interview. There were 13 cases of cancer among firefighters (ISCO 581) and 12 among the controls. A significant excess of head and neck cancers was found in firefighters in this study with the greatest difference being seen in those who had worked for more than 10 years in the occupation. The number of firefighters in the longest serving category and the exact job description are not documented.

A further case-control study considered 208 laryngeal cancer cases confirmed in South-West Germany between 1998 and 2000 (Santi et al., 2013) (Study 15). Controls (702) were selected randomly from the population registries of the study area. Risk factors were obtained by face-to-face interview and included data on smoking, alcohol consumption and occupational exposure. Exposure was classified by using indices of risk for each occupation but the only evidence presented for firefighters includes them in a group with cooks and waiters: the proportion people with one or other of these occupations was 1.2% for cancer cases and 0.9% among controls. The report makes no calculation of relative risk and sheds no light on the risk factors for firefighters.

A case-control study of laryngeal cancer in Turkey did not mention firefighters but used occupational data to identify exposure to a range of potential carcinogens including PAH and found an association between PAH exposure and laryngeal cancer (Elci and Akpinar-Elci, 2009). A meta-analysis of studies of laryngeal cancer investigating association with PAH exposure selected 16 studies from 92 articles initially reviewed (Wagner et al., 2015). No specific mention is made of firefighters as an at-risk group from this exposure although a positive association with exposure to PAH for cancer incidence (1.45; 95% CI 1.30-1.62) and cancer mortality (1.34; 95% CI 1.18-1.53) was concluded by the authors. A second systematic review and meta-analysis of laryngeal cancer also identified some evidence for an association between PAH exposure and laryngeal cancer (meta-RR 1.17; 95%CI 1.05-1.30) (Paget-Bailly et al., 2012)

The structure of a PAH influences whether and how the individual compound is carcinogenic. Some carcinogenic PAHs are genotoxic and induce mutations that initiate cancer; others are not genotoxic and instead affect cancer promotion or progression. Formaldehyde is also found in fire-smoke and has been associated with nasopharyngeal cancer. Nasal cancer has also been associated with exposure to nickel, (Grimsrud and Peto, 2006).

Conclusion

The degree of statistical association of head and neck cancer with the occupation of firefighters is classified as **limited**, based on the statistically significant relative risk seen in two studies and the absence of any evidence in the remaining studies. The known association between PAH exposure and cancer at this site, and the evidence of a possible association with length of employment in one study but no evidence from four other studies mean that the balance of evidence from the new data is considered to be **weak**.

Table 7: Summary of data on head & neck cancer in firefighters

	Mortality		Incidence	
Study number and Reference	**All firefighters (SMR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**	**All firefighters (SIR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**
1:(Daniels et al., 2014)	—	**1.40 (1.13-1.72)**[2] **(Buccal & Pharynx)**	**1.41 (1.20-1.66)**[3] **(Buccal & Pharynx)**	—
3: (Pukkala et al., 2014)	—	—	1.06 (0.72-1.50) **(Larynx)** 1.00 (0.60-1.57) **(Pharynx)**	—
5: (Amadeo et al., 2015)	1.10 (0.73-1.59) **(Larynx & Trachea)** 1.15 (0.89-1.46) **(Lip, oral, pharynx)**	—	—	—
6: (Glass et al., 2016)	—	—	0.93 (0.73-1.16) **(Lip, oral, pharynx)**	—
9: (Kang et al., 2008)	—	—	**SMOR** 1.10 (0.24-5.06) **(Lip)** 0.72 (0.37-1.41) **(Buccal cavity)** 1.17 (0.19-7.17) **(Nasopharynx)**	—
11: (Tsai et al., 2015)	—	—	1.18 (0.82-1.70) **(Tongue)** 1.07 (0.62-1.85) **(Gum & Mouth)** 1.06 (0.75-1.50) **(Pharynx)** 0.59 (0.39-0.89) **(Larynx)**	—
14: (Paget-Bailly et al., 2013)	—	—	**3.9 (1.4-11.2)**	Emp. ≤ 10 yrs. 0.5 (0.1-3.8) Emp. > 10 yrs. **7.6 (2.4-24.0)**

— Analysis not part of objectives or not shown; Ff = Firefighter
Superscripts beside data indicate the following:
[1] compared to local state populations; [2] compared to US population; [3] restricted to 1[st] cancers; [4] compared to Korean population; [5] compared to other Emergency responders; [6] compared to all other occupation; [7] compared to police

4.7 Kidney

Data on the relevant results for kidney cancer risk in the studies considered in section 1 is shown in Table 8 below. Two cohort studies retrieved for this review identified an excess of kidney cancers in firefighters (Daniels et al., 2014; Glass et al., 2016) (Studies 1 and 6). The remaining studies identified no association with cancer at this site. Limited evidence of increased risk with increased exposure derives from the observation of marginally higher rates of renal cancer in firefighters with > 20 years employment compared with those with less (Study 6), although other studies did not show any such association, However, a supplementary analysis of Study 1, according to age at diagnosis showed a higher cancer risk for men diagnosed between 17 and 64 years (Daniels et al. 2014).

A case-control study of 1,217 renal cell carcinoma cases diagnosed in the Detroit and Chicago population between 2002 and 2007 used 1,235 controls recruited from the general population of the same regions, matched for age, sex, and ethnicity (Karami et al., 2012) (Study 16). Occupation and lifestyle data were obtained by interview and the analyses adjusted for hypertension, smoking, BMI and family history of cancer. The OR for firefighting occupations was 1.4 (0.4-4.7) based on 8 cases and 7 controls, the OR was 1.1 (0.3-4.8) in those with > 5 years in firefighting. A further study of 992 cases of renal cell carcinoma diagnosed between 1999 and 2003 in seven cities (Prague, Brno, Ceske Budejovice, Olomouc, Lodz, Bucharest, and Moscow) used 1,465 controls matched from non-cancer hospital patients (Heck et al., 2010) (Study 17). Occupational data were determined from interviews and analyses were adjusted for study centre, age, sex, smoking, BMI, hypertension, education and alcohol. There were only 3 cases in firefighters compared with 1 in controls (OR 4.99 95% CI 0.50-49.9).

Apart from the above two studies, the case-control studies of renal cancer did not mention firefighters or identify any association between the occupation of firefighter and renal cancer.

Conclusion

A significant association of renal cancer with the occupation of firefighter is seen in three of ten studies, with a marginal increase in a fourth; the degree of statistical association is therefore classified as **mixed**. Trichlorethylene exposure is known to be associated with renal cancer; however, there is no evidence of exposure of firefighters to this chemical. The new data shows only limited evidence of increased exposure-related incidence in those studies where this was studied. On balance, the evidence for association from the new data is considered to be **weak-moderate**.

Table 8: Summary of data on kidney cancer in firefighters

	Mortality		Incidence	
Study number and Reference	**All firefighters (SMR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**	**All firefighters (SIR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**
1: (Daniels et al., 2014)	**1.29 (1.05-1.58)[2]**	0.97 (0.51-1.66) (San Francisco) **1.51 (1.14-1.96)** (Chicago) 1.06 (0.68-1.56) (Philadelphia)	**1.24 (1.04-1.48)[3]**	**Age at diagnosis** **17-64 yrs. 1.41 (1.12-1.76)** 65-85 yrs. 1.17 (0.94-1.44)
2: (Daniels et al., 2015)	—	—	0.94 (0.75-1.17)	—
5: (Amadeo et al., 2015)	0.63 (0.30-1.16)	—	—	—
6: (Glass et al., 2016)	—	—	1.08 (0.81-1.41)	10-20 yrs. 6.95 (0.85-56.81)[8] **> 20 yrs. 8.19 (1.01-66.62)[8]**
7: (Ahn et al., 2012)	—	—	**1.56 (0.95-2.41)[4]** 0.69 (0.21-2.26)[5]	< 10 yrs. 1.62 (0.59-3.52)[4] ≥ 10 yrs. 1.54 (0.84-2.58)[4]
9: (Kang et al., 2008)	—	—	SMOR 1.34 (0.90-2.01)[7] 1.01 (0.74-1.38)[8]	
10: (Bates, 2007)	—	—	0.98 (0.81-1.20)[10] 1.07 (0.87-1.31)[9]	—
11: (Tsai et al., 2015)	—	—	**1.27 (1.01-1.59)**	—
16: (Karami et al., 2012)	—	—	1.4 (0.4-4.7)	Empl. < 5 yrs. 3.2 (1.0-8.8E+09) Empl. ≥ 5 yrs. 1.1 (0.3-4.8)
17: (Heck et al., 2010)	—	—	4.99 (0.50-49.9)	—

— Analysis not part of objectives or not shown; Ff = Firefighter
Superscripts beside data indicate the following:
[1] compared to local state populations; [2] compared to US population; [3] restricted to 1st cancers; [4] compared to Korean population; [5] compared to other Emergency responders; [6] compared to all other occupation; [7] compared to police:[8] Full-time firefighters; [9] compared to all other cancers; [10] compared to selected cancers (excluding those potentially related to firefighting)

4.8 Leukaemia

Data on the relevant results for leukaemia risk in the studies considered in section 1 is shown in Table 9 below. Leukaemia mortality was considered in one study in relation to surrogate measures of exposure, but with only one marginally significant association (Daniels et al. 2015) (Study 2). An association of leukaemia with the occupation of firefighter has been identified in one case-control study of firefighters (Tsai et al., 2015) (Study 11). An association between work as a firefighter and lympho-haematopoietic cancer was identified in Study 6, (Glass et al., 2016); this category may include leukaemia.

No direct evidence for an association between work as a firefighter and leukaemia was found in the case-control studies and meta-analyses reviewed, many of these concentrated on exposure to previously established risk factors rather than studying specific occupations. Although positive associations with benzene, toluene, butadiene and trichlorethylene exposure were confirmed by some of the studies, firefighter exposure to these chemicals was not considered or mentioned.

Conclusion

Two of eight studies showed a significant association of leukaemia with the occupation of firefighter and a third study showed a marginal effect. The degree of statistical association is therefore concluded to be **limited**, based on these new data. In view of the identified potential exposure of firefighters to benzene and the link between such exposure and leukaemia there is a plausible explanation for such an association, as benzene exposure has been associated with haematopoietic cancers historically, with a good mechanistic explanation for this effect. The evidence for association in the new data is considered to be **weak**, due in part to the limited evidence for increased relative risk with increased exposure and in part to the effects in one study being related to more general lympho-haematopoietic cancer rather than leukaemia.

Table 9: Summary of data on leukaemia in firefighters

	Mortality		Incidence	
Study number and Reference	**All firefighters (SMR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**	**All firefighters (SIR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**
1:(Daniels et al., 2014)	1.10 (0.91-1.31)	—	0.93 (0.83-1.16)[3]	—
2: (Daniels et al., 2015)	—	**RR for 75th vs. 25th percentile** Exposed days 1.38 (0.75-2.64) **Fire-runs 1.45 (1.00-2.35)** Fire-hours 1.32 (0.87-2.36)	—	**RR for 75th vs. 25th percentile** Exposed days 0.99 (0.56-1.89) Fire-runs 1.08 (0.75-1.84) Fire-hours 0.90 (0.68-1.30)
3: (Pukkala et al., 2014)	—	—	1.27 (0.79-1.94)	—
6: (Glass et al., 2016)	—	—	1.00 (0.73-1.35)	Lympho-haematopoietic cancer **10-20 yrs. 2.38 (1.08-5.26)** **> 20 yrs. 3.08 (2.32-7.20)**
7: (Ahn et al., 2012)	—	—	1.68 (0.22-13.06)[6]	< 10 yrs. 1.60 (0.64-3.31) ≥ 10 yrs. 0.75 (0.27-1.62)
8: (Ahn and Jeong, 2015)	0.66 (0.24-1.44)	< 10 yrs. 0.33 (0.00-1.86) 10-20 yrs. 0.83 (0.17-2.42) ≥ 20 yrs. 0.81 (0.09-2.91)	—	—
9: (Kang et al., 2008)	—	—	**SMOR** 0.72 (0.43-1.20)[7] 0.98 (0.69-1.39)[6]	—
10: (Bates, 2007)	—	—	1.13 (0.92-1.37)[8] **1.22 (0.99-1.49)**[9]	—
11: (Tsai et al., 2015)	—	—	**1.32 (1.05-1.66)**	—

— Analysis not part of objectives or not shown; Ff = Firefighter
Superscripts beside data indicate the following:
[1] compared to local state populations; [2] compared to US population; [3] restricted to 1st cancers; [4] compared to Korean population;
[5] compared to other Emergency responders; [6] compared to all other occupation; [7] compared to police; [8] compared to all other cancers;
[9] compared to selected cancers (excluding those potentially related to firefighting)

4.9 Lung

Data on the relevant results for lung cancer risk in the studies considered in section 1 is shown in Table 10 below. Three studies of all firefighters combined, identified an excess of lung cancer with the excess confined to non-specific non-small-cell cancer only in one of these (Studies 1, 3 and 11). There was no adjustment for smoking in any of the studies but, where available, the evidence suggests that firefighters generally smoke slightly less than the general population so smoking does not seem a likely explanation. One of these studies examined dose-response relationships using various measures of exposure and demonstrated higher rates of lung cancer and lung cancer mortality in those firefighters spending most time at fires compared to those spending less time (Daniels et al., 2015) (Study 2). The results from Study 2 seem of particular importance as these authors quantified exposure to fires and reported the dose-response; a positive dose response relationship was found overall but in one of the three sub-cohorts (Philadelphia) forming the study population, rates were significantly lower in those with longer time at fires. A second study found a significant excess of lung cancer in the oldest (>70 years) members of the cohort; a group who also showed an excess of mesothelioma (Pukkala et al., 2014) (Study 3). Two cohort studies, in France and in Australia did not find any excess, while a study from Korea found a significant decrease in mortality compared to the general population.

A multi-centre study of lung cancer in firefighters appears to present a large body of data from many separate sources but the number of firefighters is only 86 cases and 104 controls, thus has less statistical power than would first appear (Bigert et al., 2016) (Study 12). The study has some strength in identifying by interview the occupational profile of each individual and the smoking history. In the analysis, they adjusted for employment in jobs known to present an excess risk of lung cancer, such as occupations in the mining and quarrying industry, asbestos production, metals industry, construction industry and shipbuilding and the cumulative cigarettes smoked and time since quitting. The study is reported in terms that do not fully describe the methodology, while indicating that factors such as control selection were not identical in each location. The analysis indicates that, while there is a similar likelihood of being a smoker amongst firefighters and controls, the firefighters are more likely to be in the 20+ pack-years category. None of the analyses showed evidence of an association between the occupation of firefighter and lung cancer. This case-control study of lung cancer in firefighters is based on interviews with 14,748 cases of lung cancer and 17,543 controls with a focus on lifetime occupational histories.

A case-control study of 457 cases of lung cancer aged 20-75 years from the New Zealand cancer registry in 2007 and 2008 and 792 age-matched controls recruited from the New Zealand electoral register examined associations with all occupations (Corbin et al., 2011) (Study 18). Occupation details for all employments > 12 months and lifestyle information were collected by interview; in the case of 364 controls this was by telephone while all others were face-to-face. Analyses were adjusted for age, gender, ethnicity, smoking and socio-economic status. Because of the multiple hypotheses examined, a statistical method known as Bayes shrinkage was applied to make the findings more robust. A total of 3 firefighters (New Zealand Standard Classification of Occupations, NZSCO 1999 category 5151) were identified among the cases and 5 among the controls, giving an adjusted OR of 1.20 (95% CI 0.51-2.83) after the Bayes method was applied.

In a further case-control study which looked for association with PAHs, 2,852 lung cancer cases < 75 years old from 16 centres (Borsod, Heves, Szabolcs, Szolnok, Budapest (Hungary), Lodz, Warsaw (Poland), Banska Bystrica, Bratislava, Nitra (Slovakia), Brno, Olomouc, Prague (Czech Republic), Bucharest (Romania), Moscow (Russia) and Liverpool (UK) between 1998 and 2002 were compared with 2,923 age and gender-matched controls, the latter were selected in different ways in different centres (Olsson et al., 2010) (Study 19). Face-to-face interviews with a semi-structured format were conducted with a focus on 16 occupational activities and 70 agents. This information was used to construct a cumulative measure of exposure to PAHs across all employments based on estimated concentration, frequency and duration. Firefighters were classified as exposed to PAHs with 5 firefighters among the cases and 5 among the controls. The relative risk for firefighters was not calculated. The study found no evidence for an increased risk of lung cancer among workers exposed to PAHs in most of the centres, but UK was an exception with a significant linear trend for cumulative exposure ($p < 0.01$) and years exposed ($p < 0.04$) to PAHs. The difference between UK and other sites is not adequately explained.

In a study examining links with diesel and gasoline, male lung cancer cases (857) in the Montreal area between 1979 and 1985 were compared with two sets of controls (Parent et al., 2007) (Study 20). The first control set was 533 population controls from the local area while the second set were 1,349 cancer patients diagnosed in the same year and hospital as cases. The cases and controls were all interviewed to obtain detailed information jobs and tasks and lifestyle throughout their working life. A team of hygienists who were unaware of the case/control status of participants translated this information into potential exposure to around 300 substances. Their assessments were graded by confidence that it had occurred, a three-category ranking of concentration (low, medium or high) and by frequency (< 5%, 5-30%, or > 30% of working week). It is not clear how many firefighters were in the study but 94% of them were classified with high confidence as exposed to gasoline and to diesel emissions at a medium concentration between 5 and 30% of a normal work-week. No specific conclusions were made for firefighters however the study failed to find any evidence for an association between lung cancer and exposure to gasoline. The results for diesel were less clear as they differed according to which control group was used. The authors regarded the results as showing limited support for an excess due to diesel exhaust in those with the highest exposure concentration but not at the medium level which is of most relevance here.

A similar case-control study investigating associations with diesel and gasoline in eight Canadian provinces was based on 1,681 male lung cancer cases reported to cancer registries between 1994 and 1997, and 2,053 controls from the general population (Villeneuve et al., 2011) (Study 21). As in study 20, the assessment of exposure – concentration, frequency and confidence – was carried out blind to case/control status and based on detailed occupational histories. After adjusting for age, province, smoking and silica exposure, an analysis of exposure to gasoline and diesel emissions showed no evidence of an excess of lung cancer with gasoline exposure. The authors considered that there was evidence of a dose-response relationship with diesel emission exposure but the OR for the high concentration group was not significant (OR 1.34, 0.89-2.01). An analysis of occupation related to lung cancer found 22 cases of lung cancer among firefighters and 18 in the controls. The adjusted OR for firefighters was 1.70 (95% CI; 0.84-3.43). The same study detected a significant excess of cases in several occupations, such as motor transport workers, mechanics, miners and quarrymen.

The association between lung cancer and asbestos was examined in the same eight Canadian provinces in a case-control design almost identical to study 21: there were 1,681 lung cancer cases and 2053 controls (Villeneuve et al., 2012) (Study 22).The methods for eliciting occupational histories were similar to the diesel study but here the focus was on assessing potential for exposure to asbestos in each job with each assessment graded by concentration, frequency and confidence (reliability) as before. Firefighters comprised 3.9% of the cases and were classified as definitely being exposed to asbestos with a medium frequency (5-30% of work time) at a low concentration (< 5 fibres/cc). No specific conclusions were reached on the risk to firefighters. The study results supported the established link between asbestos exposure and lung cancer with an OR of 2.16 (1.21-3.88) for medium/high exposure and an OR of 1.17 (0.92-1.50) for low exposure.

A case-control study from British Columbia compared occupational histories of 2,998 lung cancer cases reported to the cancer registry from 1983-1990 and 10,223 controls; the controls were other cancer cases from the same registry matched for age and year of diagnosis (MacArthur et al., 2009) (Study 23). Questionnaires covering employment, education, smoking and alcohol consumption were mailed to potential participants and 60% were returned; proxy respondents provided the information for 28% of cases and 18% of controls. Adjustments for confounders differed between analyses but seem to have always included measures of alcohol consumption, smoking and education. The authors identified an excess of lung cancer in protective service workers, which included firefighters, but did not break down the results further by occupation. As noted in section 1.3, Canadian census data indicate that firefighters comprise around 10% of protective services workers.

A review of carcinogenicity of some PAHs made no mention of lung cancer risk to firefighters (IARC, 2010b), but a more recent review of occupational cancer found firefighters to be at risk of lung cancer due to potential exposure to PAHs and soot (Brown et al., 2012).

Conclusion

The evidence for an association of the occupation of firefighter with lung cancer is inconsistent, with four of the eleven studies reporting lung cancer rates finding evidence of an association. However, seven studies did not report an association. Overall the data is concluded to be consistent with the classification of **mixed** for the degree of statistical association of lung cancer with occupation of firefighter.

The case-control studies looking at exposure to specific agents do not provide any evidence that exposure of firefighters to gasoline, diesel or PAHs is associated with an excess risk of lung cancer. However, one study, which made some attempt to measure exposure to fires, did show a positive dose-response relationship overall, but this was inconsistent between sub-cohorts. It is also recognised that asbestos exposure, which leads to mesothelioma will also be associated with lung cancer (Nielsen et al., 2014). Since firefighters have been classified by one study as certainly exposed to asbestos (Villeneuve et al., 2012), the potential association of lung cancer with occupation as firefighter is plausible and the mechanism of asbestos exposure leading to lung cancer is well established even without the development of asbestosis (IARC, IARC, 1977). Although the evidence is generally rather weak, the link of lung cancer with asbestos exposure and the limited evidence of some dose-response relationship with firefighting has been considered sufficient to justify a classification of **weak-moderate** for the quality of evidence.

Table 10: Summary of data on lung cancer in firefighters

	Mortality		Incidence	
Study number and Reference	**All firefighters (SMR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**	**All firefighters (SIR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**
1:(Daniels et al., 2014)	**1.10 (1.04-1.17)**	—	**1.13 (1.04-1.22)**[3]	—
2: (Daniels et al., 2015)	—	**RR for 75th vs. 25th percentile** Exp. days 0.93 (0.86-1.03) **Fire-runs 1.11 (0.95-1.29)** **Fire-hours 1.39 (1.12-1.73)**	—	**RR for 75th vs 25th percentile** Exp. days 1.05 (0.84-1.33) Fire-runs 1.10 (0.94-1.28) **Fire-hours 1.39 (1.10-1.74)**
3: (Pukkala et al., 2014)	—	—	**1.29 (1.02-1.60)**	**Age ≥70 yrs. 1.90 (1.34-2.62)**
5: (Amadeo et al., 2015)	0.86 (0.74-0.99)	—	—	—
6: (Glass et al., 2016)	—	—	0.71 (0.58-0.86)	—
7: (Ahn et al., 2012)	—	—	0.78 (0.55-1.09)[4] 0.69 (0.21-2.26)[6]	Emp. < 10 yrs. 0.69 (0.28-1.43) Emp. ≥ 10 yrs. 0.81 (0.54-1.16)
8: (Ahn and Jeong, 2015)	0.58 (0.38-0.84)	Emp.<10 yrs. 0.69 (0.25-1.48) Emp.10-20 yrs. 0.53 (0.21-1.10) Emp. ≥ 20 yrs. 0.56 (0.30-0.96)	—	—
9: (Kang et al., 2008)	—	—	**SMOR** 1.02 (0.79-1.31)[7] 0.91 (0.76-1.10)[6]	—
10: (Bates, 2007)	—	—	0.92 (0.84-1.01)[9] 0.98 (0.88-1.09)[10]	—
11: (Tsai et al., 2015)	—	—	1.08 (0.92-1.28) **2.01 (1.38-2.93)**[8]	—
12: (Bigert et al., 2016)	—	—	0.95 (0.68-1.32)	Emp.< 6 yrs. 1.19 (0.65-2.15) Emp.6-21 yrs. 0.99 (0.52-1.86) Emp.22-32 yrs. 0.70 (0.32-1.50) Emp.> 32 yrs. 0.91 (0.47-1.77)
18: (Corbin et al., 2011)	—	—	1.20 (0.51-2.83)	—
21: (Villeneuve et al., 2011)	—	—	1.70 (0.84-3.43)	—

— Analysis not part of objectives or not shown; Ff = Firefighter
Superscripts beside data indicate the following:
[1] compared to local state populations; [2] compared to US population; [3] restricted to 1st cancers; [4] compared to Korean population; [5] compared to other Emergency responders; [6] compared to all other occupation; [7] compared to police; [8] Non-specific non-small-cell; [9] compared to all other cancers; [10] compared to selected cancers (excluding those potentially related to firefighting)

4.10 Mesothelioma

Data on the relevant results for mesothelioma risk in the studies considered in section 1 is shown in Table 11 below. Mesothelioma incidence was higher than controls in firefighters in the two cohort studies of the longest duration (Studies 1 and 3). Since the latency for mesothelioma is > 30 years and since it is most frequently associated with asbestos exposure this association may represent exposure of firefighters to asbestos at a time (pre-1980) when protective equipment was not at the standard in present use. Personal respirators worn today are probably better adjusted and worn for a longer duration.

Interestingly, the three case-control studies which focussed on firefighter risks did not investigate links with mesothelioma (Studies 9,10,11); indeed, it was probably included as a 'control' cancer in the Massachusetts study (Study 9). But a later study also based on the Massachusetts cancer registry focussed on the 1,424 cases of mesothelioma reported there between 1988 and 2003 (Roelofs et al., 2013) (Study 24). They used computer software to code the information given in the Registry for usual occupation and industry; 564 cases (40%) were coded for occupation and 38% for industry. The cases were compared with 80,184 cancer cases that were not known to have any association with asbestos. Among the cases of mesothelioma 19 listed firefighting as occupation; the OR for firefighters compared to all other occupations, except 32 construction trades known to be at increased risk, was 2.2 (1.4-3.4). The authors noted that it is not possible to judge whether they were firefighters at the time that relevant exposure might have occurred, since full employment histories were not available to the study.

Many other case-control studies were retrieved for mesothelioma and association with occupation; however, the majority did not study specific occupations but used asbestos exposure as the occupational measure, thus firefighters were not mentioned.

Conclusion

Taking account of all the data retrieved in this review it is concluded that **a consistent association between mesothelioma and the occupation of firefighter is shown** by the only studies capable of demonstrating this association. The association of asbestos exposure with the development of mesothelioma is well established within the clinical and scientific literature and is usually indicative of asbestos exposure. The evidence for the association is also considered to be **strong**.

Table 11: Summary of data on mesothelioma in firefighters

	Mortality		Incidence	
Study number and Reference	**All firefighters (SMR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**	**All firefighters (SIR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**
1:(Daniels et al., 2014)	**2.00 (1.03-3.49)**	—	**2.00 (1.31-2.93)**	—
3: (Pukkala et al., 2014)	—	—	1.55 (0.90-2.48)	Age 30-49 yrs. 1.02 (0.03-5.69) **Age ≥ 70 yrs. 2.59 (1.24-4.77)**
6: (Glass et al., 2016)	—	—	1.34 (0.75-2.21)	—
24: (Roelofs et al., 2013)	—	—	**2.2 (1.4-3.4)**	—

— Analysis not part of objectives or not shown; Ff = Firefighter
Superscripts beside data indicate the following:
[1] compared to local state populations; [2] compared to US population; [3] restricted to 1st cancers; [4] compared to Korean population;
[5] compared to other Emergency responders; [6] compared to all other occupation; [7] compared to police

4.11 Multiple Myeloma

Data on the relevant results for multiple myeloma risk in the studies considered in section 1 is shown in Table 12 below. Multiple myeloma was identified as potentially associated with firefighters in only one of three cohort studies which addressed it (Pukkala et al., 2014) (Study 3), and then only showed a significant excess in the group of firefighters aged > 70 years. The only case-control study which addressed this outcome found evidence of an excess of this cancer in California firefighters (Tsai et al., 2015) (Study 11); the excess was only borderline significant.

Other case-control studies of multiple myeloma and occupation did not specifically mention firefighters or reveal any relevant association.

Conclusion

There are only two studies out of six reporting this cancer type which show some evidence for an association between multiple myeloma and the occupation of firefighter, and both of these are rather borderline significant. On the basis of the classification system used the degree of statistical association must be regarded as **limited**. Since there are no known substances in the exposure profile of firefighters which are associated with this type of cancer, and the evidence is extremely limited, the strength of the evidence is concluded to be **very weak**.

Table 12: Summary of data on multiple myeloma in firefighters

	Mortality		Incidence	
Study number and Reference	**All firefighters (SMR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**	**All firefighters (SIR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**
1:(Daniels et al., 2014)	0.89 (0.64-1.20)	—	0.75 (0.52-1.06)[3]	—
3: (Pukkala et al., 2014)	—	—	1.13 (0.81-1.53)	**Age ≥ 70 yrs. 1.69 (1.08-2.51)**
6: (Glass et al., 2016)	—	—	1.00 (0.59-1.58)	—
9: (Kang et al., 2008)	—	—	**SMOR** 0.70 (0.39-1.48)[7] 0.92 (0.59-1.47)[6]	—
10: (Bates, 2007)	—	—	0.97 (0.70-1.34)[8] 1.03 (0.75-1.43)[9]	—
11: (Tsai et al., 2015)	—	—	**1.35 (1.00-1.82)**	—

— Analysis not part of objectives or not shown; Ff = Firefighter
Superscripts beside data indicate the following:
[1] compared to local state populations; [2] compared to US population; [3] restricted to 1st cancers; [4] compared to Korean population; [5] compared to other Emergency responders; [6] compared to all other occupation; [7] compared to police; [8] compared to all other cancers; [9] compared to selected cancers (excluding those potentially related to firefighting)

4.12 Non-Hodgkin lymphoma (NHL)

Data on the relevant results for NHL risk in the studies considered in section 1 is shown in Table 13 below. NHL was associated with the occupation of firefighter in some analyses from three of the cohort studies and in two of those showed some evidence of association with length of employment (Daniels et al., 2014; Glass et al., 2016) (Studies 1 and 6). One case-control study showed a borderline significant excess risk for firefighters (Tsai et al., 2015) (Study 11).

The occupational profile of 291 cases of NHL from New Zealand was compared with that of 471 population controls ('t Mannetje et al., 2008) (Study 25). Occupation details for all employments > 12 months and lifestyle information were collected by interview. They set out to investigate ORs for over 900 occupations with adjustment for age, gender, ethnicity, smoking and socio-economic status. Firefighters were considered *a priori* to be a possible high-risk group but they did not show any data for them, or other occupations where the numbers of cases and controls combined was considered too small, (*i.e.* < 10).

Review of all other retrieved case-control studies did not identify any association of this cancer with the occupation of firefighter, however many were concentrating on the potential association with exposure to solvents including benzene and trichloroethylene. In most studies, analysis was confined to occupational groups with large enough numbers to allow an assessment of the significance of any association. If firefighters were present at all in the populations studied, the numbers were too small to assess and mention.

Occupational exposures associated with NHL have been identified for woodworkers and others exposed to high levels of organic solvents (Boffetta and de Vocht, 2007). Benzene exposure is not uncommon and other solvents may well also be involved such as trichloroethylene, carbon tetrachloride formaldehyde and toluene. The postulated mechanism is immunological with the involvement of interleukin and failure of tumour suppression.

A multi-centre case-control study of environmental exposure and lymphoid neoplasms included 2,348 lymphoma cases and 2,462 controls (Cocco et al., 2010). Controls in all centres were non-cancer patients although the mechanism of selection differed slightly between centres. Information on occupation and lifestyle were obtained by interview. Based upon the description of occupation, an estimate was made of potential exposure to 43 agents. No mention was made of firefighters in this analysis. Solvent exposure was positively associated with an increased risk of lymphoid cancer, particularly chronic lymphocytic leukaemia.

Conclusion

The association between occupation of firefighter and NHL is found in 5 of eight studies identified in the current review. As a result, the degree of statistical association is classified as **mixed**.

Some of the evidence for the association derives from the relationship between exposure duration and risk in two studies, and the potential association with some solvent exposures, which may well occur in firefighting. The classification of the evidence for the association is thus concluded to be **moderate**. This is consistent with the conclusions of the previous IARC review (IARC, 2010a) which found approximately 20% excess NHL, based upon seven studies and > 300 cases.

Table 13: Summary of data on NHL in firefighters

	Mortality		Incidence	
Study number and Reference	**All firefighters (SMR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**	**All firefighters (SIR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**
1:(Daniels et al., 2014)	1.17 (0.97-1.40)	—	0.99 (0.83-1.16)[3]	Emp. < 10 yrs. 0.98 (0.58-1.55) Emp. 10-<20 yrs. 0.51 (0.23-0.96) **Emp. 20-<30 yrs. 1.35 (1.04-1.73)** **Emp. ≥ 30 yrs. 1.47 (1.01-2.06)**
2: (Daniels et al., 2015)	—	Exp. days 1.30 (0.93-2.06) Fire-runs 0.70 (0.42-1.10) Fire-hours 0.54 (NC-1.08)	—	**RR for 75th vs. 25th percentile** Exp. days 1.07 (0.92-1.28) Fire-runs 0.79 (0.64-1.10) Fire-hours 1.12 (0.89-1.50)
3: (Pukkala et al., 2014)	—	—	1.04 (0.83-1.29)	Age ≥ 70 yrs. 1.30 (0.89-1.83)
6: (Glass et al., 2016)	—	—	0.97 (0.75-1.24)	Emp. 10-20 yrs. 2.12 (0.71-6.34) **Emp. ≥ 20 yrs. 3.67 (1.28-10.54)**
7: (Ahn et al., 2012)	—	—	**1.69 (1.01-2.67)**[4] 0.52 (0.15-1.78)[6]	Emp.< 10 yrs. 1.68 (0.62-3.67) Emp.≥ 10 yrs. 1.69 (0.87-2.96)
9: (Kang et al., 2008)	—	—	**SMOR** 0.77 (0.31-1.92)[7] 1.10 (0.58-2.09)[6]	—
10: (Bates, 2007)	—	—	0.98 (0.84-1.15)[8] 1.07 (0.90-1.26)[9]	—
11: (Tsai et al., 2015)	—	—	**1.22 (1.00-1.50)**	—

— Analysis not part of objectives or not shown; Ff = Firefighter

Superscripts beside data indicate the following:

[1] compared to local state populations; [2] compared to US population; [3] restricted to 1st cancers; [4] compared to Korean population;
[5] compared to other Emergency responders; [6] compared to all other occupation; [7] compared to police; [8] compared to all other cancers;
[9] compared to selected cancers (excluding those potentially related to firefighting)

4.13 Oesophagus

Data on the relevant results for oesophageal cancer risk in the studies considered in section 1 is shown in Table 14 below. The oesophagus has been identified by one cohort study (Daniels et al., 2014) (Study 1) as a site for cancer associated with firefighters but not in three other cohort studies. There was no evidence of a relationship with time spent at fires in the study which investigated that relationship (Daniels et al., 2015) (Study 2). Two case-control studies in firefighters (Bates, 2007; Tsai et al., 2015) (Studies 10 and 11) also identify an excess risk for firefighters for cancer at this site.

Other case-control studies of oesophageal cancer were reviewed but did not mention firefighters or identify firefighters as an occupational group at risk from this cancer.

There are no occupational exposures of firefighters which have been consistently associated with cancer of the oesophagus, although a meta-analysis of 20 oesophageal cancer cohort studies and asbestos exposure concluded that such exposures might be associated with an increased risk of cancer of the oesophagus (SMR 1.24; 95% CI 1.13-1.38) (Li et al., 2015). This cancer is known to be associated both with tobacco and alcohol consumption. However, where available, the evidence suggests that firefighters generally smoke slightly less than the general population. On the other hand, alcohol consumption is said to be greater in the fire service and particularly in the active, emergency-responding firefighters than in the general population (Piazza-Gardner et al., 2014). The origins of the excess of this cancer in some studies of firefighters cannot be concluded from the data available, but may not be related directly to occupation.

Conclusion

Three of eight studies reporting this cancer type showed a significant association of oesophageal cancer with occupation of firefighter although the RR was generally < 1.5 and significance quite marginal. Based on the classification scheme applied to these new data the degree of statistical association is **mixed.**

One study showing an association with duration of employment cannot be ignored; however, the lack of known causative agents in the exposures experienced by firefighters and the inconsistent pattern of findings in the studies reviewed means that the evidence for such an association is generally **weak**.

Table 14: Summary of data on oesophageal cancer in firefighters

	Mortality		Incidence	
Study number and Reference	**All firefighters (SMR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**	**All firefighters (SIR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**
1:(Daniels et al., 2014)	**1.39 (1.14-1.67)**	—	**1.09 (1.06-1.12)**[3]	Emp. < 10 yrs. 1.17 (0.62-2.00) **Emp. 10-<20 yrs. 1.72 (1.14-2.48)** **Emp. 20-<30 yrs. 1.40 (1.05-1.83)** Emp. ≥ 30 yrs. 1.18 (0.71-1.84)
2: (Daniels et al., 2015)	—	**RR for 75th vs. 25th percentile** Exp. days 0.61 (NC-1.10) Fire-runs 1.24 (0.91-1.88) Fire-hours 1.18 (0.80-1.98)	—	**RR for 75th vs. 25th percentile** Exp. days 0.66 (0.42-1.18) Fire-runs 1.22 (0.89-1.88) Fire-hours 0.57 (NC-1.85)
5: (Amadeo et al., 2015)	0.93 (0.67-1.27)	—	—	—
6: (Glass et al., 2016)	—	—	0.78 (0.46-1.26)	—
7: (Ahn et al., 2012)	—	—	0.75 (0.28-1.64)	Emp. ≥ 10 yrs. 0.94 (0.34-2.05)
9: (Kang et al., 2008)	—	—	0.93 (0.61-1.41)[7] 0.64 (0.47-0.87)[6]	—
10: (Bates, 2007)	—	—	**1.37 (1.06-1.76)**[8] **1.48 (1.14-1.91)**[9]	—
11: (Tsai et al., 2015)	—	—	**1.59 (1.20-2.09)**	—

— Analysis not part of objectives or not shown; Ff = Firefighter
Superscripts beside data indicate the following:
[1] compared to local state populations; [2] compared to US population; [3] restricted to 1st cancers; [4] compared to Korean population;
[5] compared to other Emergency responders; [6] compared to all other occupation; [7] compared to police; [8] compared to all other cancers;
[9] compared to selected cancers (excluding those potentially related to firefighting)

4.14 Pancreas

Data on the relevant results for pancreatic cancer risk in the studies considered in section 1 is shown in Table 15 below. Increased risk of cancer of the pancreas among firefighters was not identified by any of the studies in firefighters.

Review of the retrieved data on case-control studies of pancreatic cancer did not identify any further studies in which firefighters were mentioned, or any association with firefighters.

Conclusion

None of the studies retrieved in this review showed any evidence of association of pancreatic cancer with occupation of firefighter. There is also no evidence for any chemical exposures experienced in firefighting which might be associated with pancreatic cancer. Thus, the current review provides **no evidence** for this association.

Table 15: Summary of data on pancreatic cancer in firefighters

	Mortality		Incidence	
Study number and Reference	**All firefighters (SMR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**	**All firefighters (SIR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**
3: (Pukkala et al., 2014)	—	—	1.17 (0.94-1.45)	—
5: (Amadeo et al., 2015)	1.27 (0.92-1.72)	—		—
6: (Glass et al., 2016)	—	—	1.03 (0.69-1.48)	—
7: (Ahn et al., 2012)	—	—	0.95 (0.44-1.81)	Emp. < 10 yrs. 1.80 (0.49-4.62) Emp. ≥ 10 yrs. 0.93 (0.25-2.37)
9: (Kang et al., 2008)	—	—	**SMOR** 0.86 (0.53-1.40)[7] 0.84 (0.58-1.22)[6]	—
10: (Bates, 2007)	—	—	1.16 (0.63-2.13)[8] 0.74 (0.38-1.45)[9]	—
11: (Tsai et al., 2015)	—	—	1.10 (0.83-1.46)	—

— Analysis not part of objectives or not shown; Ff = Firefighter
Superscripts beside data indicate the following:
[1] compared to local state populations; [2] compared to US population; [3] restricted to 1st cancers; [4] compared to Korean population; [5] compared to other Emergency responders; [6] compared to all other occupation; [7] compared to police; [8] compared to all other cancers; [9] compared to selected cancers (excluding those potentially related to firefighting)

4.15 Prostate

Data on the relevant results for prostate cancer risk in the studies considered in section 1 is shown in Table 16 below. Increased risk of prostate cancer in firefighters has been identified in two of the five independent cohort studies (Pukkala et al., 2014; Glass et al., 2016) (Studies 3 and 6), with some evidence of exposure-related risk in study 6, which attempted to quantify exposure, but not in the other study which also attempted this (Daniels et al., 2015) (Study 2). Two case-control studies in firefighters also identified an association (Bates, 2007; Tsai et al., 2015) (Studies 10 and 11); as mentioned previously, there is substantial overlap in the populations of these two studies based on the Californian cancer registry so these pieces of evidence are not independent.

Review of all the retrieved case-control studies on prostate cancer did not find any mention of firefighters or identify any association with the occupation of firefighter.

Conclusion

Four of eight studies reporting prostate cancer in firefighters identified an association with occupation and a further study indicated a similar effect although the result was not quite statistically significant. On this basis, the degree of statistical association of prostate cancer with occupation of firefighter is **mixed.**

There are some plausible hypotheses for prostate cancer concerning the gene-environment interaction in hormone synthesis, action and metabolism, (Gann, 2002) although particular environmental contaminants have not been identified. The evidence for an association of occupation with prostate cancer is not totally consistent from the new studies retrieved but overall is considered to be of **moderate** strength. The previous review (IARC, 2010a) performed a meta-analysis which found a 30% excess of prostate cancer, based upon 17 studies and approximately 1,800 cases. However, of the 17 studies, only 2 showed statistically significantly elevated risk estimates and one showed a trend with duration of employment.

Table 16: Summary of data on prostate cancer in firefighters

	Mortality		Incidence	
Study number and Reference	**All firefighters (SMR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**	**All firefighters (SIR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**
1:(Daniels et al., 2014)	1.09 (0.96-1.22)	—	1.03 (0.97-1.09)[3]	—
2: (Daniels et al., 2015)	—	—	—	**RR for 75th vs. 25th percentile** Exp. days 0.90 (0.77-1.05) Fire-runs 1.02 (0.91-1.14) Fire-hours 0.98 (0.90-1.09)
3: (Pukkala et al., 2014)	—	—	**1.13 (1.05-1.22)**	**Age 30-49 yrs. 2.59 (1.34-4.52)** **Age 50-69 yrs. 1.16 (1.04-1.30)** Age ≥70 yrs. 1.09 (0.98-1.21)
5: (Amadeo et al., 2015)	0.54 (0.31-0.86)	—	—	—
6: (Glass et al., 2016)	—	—	**1.31 (1.19-1.43)**	**RR for 3rd tertile vs 1st** **All fires 2.55 (1.45-4.50)** **Struct. fires 2.45 (1.40-4.26)** **Vehicle fires 2.60 (1.50-4.54)**
7: (Ahn et al., 2012)	—	—	1.32 (0.60-2.51)[4] 0.22 (0.05-1.05)[5]	Emp. < 10 yrs. 0.75 (0.01-4.16) Emp. ≥ 10 yrs. 1.47 (0.63-2.89)
9: (Kang et al., 2008)	—	—	0.98 (0.78-1.23)[7] 1.05 (0.88-1.24)[6]	—
10: (Bates, 2007)	—	—	**1.20 (1.12-1.29)[8]** **1.22 (1.12-1.33)[9]**	—
11: (Tsai et al., 2015)	—	—	**1.45 (1.25-1.69)**	—

— Analysis not part of objectives or not shown; Ff = Firefighter
Superscripts beside data indicate the following:
[1] compared to local state populations; [2] compared to US population; [3] restricted to 1st cancers; [4] compared to Korean population; [5] compared to other Emergency responders; [6] compared to all other occupation; [7] compared to police; [8] compared to all other cancers; [9] compared to selected cancers (excluding those potentially related to firefighting)

4.16 Skin

Data on the relevant results for skin cancer risk in the studies considered in section 1 is shown in Table 17 below. Two cohort studies (Pukkala et al., 2014; Glass et al., 2016) (3 and 6) of firefighters in five Nordic countries and in Australia respectively, have identified an excess of skin melanoma; but for non-melanoma skin cancer, only the study from the Nordic countries showed an association. There was no indication of an excess in a French cohort study, although this may be expected for a cancer which has a very good survival rate (Amadeo et al., 2015) (Study 5). An association with skin melanoma is also found in the two overlapping case-control studies of Californian firefighters (Bates, 2007; Tsai et al., 2015) (studies 10 and 11).

Other publications retrieved on skin cancer including case-control studies and reviews, have been reviewed and none mentioned firefighters, or gave any indication of an association of skin cancer of any type with the occupation of firefighter. There is some question as to the ability of registry studies in some countries to fully record the incidence rates of non-melanoma skin cancer where they may be diagnosed and treated outside a hospital environment; although it is considered unlikely to have significantly affected the data reviewed here.

Malignant melanoma is caused in the clear majority of cases by exposure to ultra violet radiation, usually from the sun. This causes genetic damage to the DNA of the melanocytes and the potential for malignant change. Genetic, environmental and phenotypic factors may also be involved such as fair skin, latitude, altitude and family history. Certain chemicals stimulate melanocytes to produce melanin and may be involved in dermal malignant change by sensitising the skin to ultra violet light. Such chemicals are not those associated with the work and exposures of firefighting (Stern, 2012).

Chemicals associated with non-melanoma skin cancer (*e.g.* soot and PCBs) are among the potential exposures of firefighters, however only one study identified an excess risk of non-melanoma skin cancer.

Conclusion

The data reviewed included six studies which identified skin cancer in firefighters. Of these, four had significant association of melanoma with occupation of firefighter and only one found an association of non-melanoma skin cancer. The degree of statistical association is therefore classified as **mixed** for melanoma while that for non-melanoma is considered **limited**.

Although melanoma skin cancer is reproducibly associated with the occupation of firefighter, the mechanism of this association is unclear but may be due to polychlorinated biphenyl exposure. The quality of available evidence is considered to be **weak-moderate**. The one study showing an association with non-melanoma skin cancer cannot be ignored since a potential mechanism is known, but the evidence is **very weak**.

Table 17: Summary of data on skin cancer in firefighters

	Mortality		Incidence	
Study number and Reference	**All firefighters (SMR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**	**All firefighters (SIR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**
3: (Pukkala et al., 2014)	—	—	**1.25 (1.03-1.51)[8]** **1.33 (1.10-1.59)[9]**	**Age 30-49 yrs. 1.62 (1.14-2.23)[8]** **Age ≥ 70 yrs. 1.40 (1.10-1.76)[9]**
5: (Amadeo et al., 2015)	0.65 (0.21-1.51)[10]	—	—	—
6: (Glass et al., 2016)	—	—	**1.44 (1.28-1.62)[8]**	—
9: (Kang et al., 2008)	—	—	0.65 (0.44-0.97)[7,8] 1.04 (0.77-1.42)[6,8]	—
10: (Bates, 2007)	—	—	**1.44 (1.28-1.62)[8,11]** **1.50 (1.33-1.70)[8,12]**	—
11: (Tsai et al., 2015)	—	—	**1.75 (1.44-2.13)[8]**	—

— Analysis not part of objectives or not shown; Ff = Firefighter
Superscripts beside data indicate the following:
[1] compared to local state populations; [2] compared to US population; [3] restricted to 1[st] cancers; [4] compared to Korean population; [5] compared to other Emergency responders; [6] compared to all other occupation; [7] compared to police; [8] Melanoma; [9] Non-melanoma; [10] Skin - not otherwise specified; [11] compared to all other cancers; [12] compared to selected cancers (excluding those potentially - related to firefighting)

4.17 Small intestine

Data on the relevant results for small intestine cancer risk in the studies considered in section 1 is shown in Table 18 below. None of the reviewed studies in firefighters identified a statistically significant associate with cancer of the small intestine.

No specific publications were retrieved in the searches for cancer at this site and occupational risk.

Conclusion

Taking account of all the evidence from the retrieved studies in this review, it is concluded that there is **no new solid evidence for an association** between cancer of the small intestine and the occupation of firefighter.

Table 18: Summary of data on small intestine cancer in firefighters

	Mortality		Incidence	
Study number and Reference	**All firefighters (SMR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**	**All firefighters (SIR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**
1:(Daniels et al., 2014)	1.66 (0.72-3.27)	—	1.43 (0.82-2.33[3]	
3: (Pukkala et al., 2014)	—	—	1.15 (0.61-1.97)	—
7: (Ahn et al., 2012)	—	—	2.46 (0.79-5.75)[4]	Emp. < 10 yrs. 1.81 (0.02-10.09) Emp. ≥ 10 yrs. 2.71 (0.73-6.93)

— Analysis not part of objectives or not shown; Ff = Firefighter
Superscripts beside data indicate the following:
[1] compared to local state populations; [2] compared to US population; [3] restricted to 1st cancers; [4] compared to Korean population; [5] compared to other Emergency responders; [6] compared to all other occupation; [7] compared to police; [8] compared to all other cancers; [9] compared to selected cancers (excluding those potentially related to firefighting)

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4.18 Stomach

Data on the relevant results for stomach cancer risk in the studies considered in section 1 is shown in Table 19 below. Only one of the six independent studies retrieved on cancer in firefighters identified stomach cancer as associated with occupation (Daniels et al., 2014) (Study 1). In this study, there was evidence of a relationship between mortality from stomach cancer and employment as a firefighter for over 30 years, but there was no excess in cancer incidence. Additionally, the limited available data on stomach cancer and association with occupation did not identify any association with occupation of firefighter.

Conclusion

The isolated significant finding identified in this review cannot be entirely ignored as the study considers a longer employment history then many others, but in the context of eight other studies showing no association, it is concluded that it is insufficient to be considered as new evidence for an association between firefighting and stomach cancer.

Table 19: Summary of data on stomach cancer in firefighters

	Mortality		Incidence	
Study number and Reference	**All firefighters (SMR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**	**All firefighters (SIR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**
1:(Daniels et al., 2014)	1.10 (0.91-1.33)	Emp. < 10 yrs. 0.80 (0.41-1.40) Emp. 10-<20 yrs. 0.92 (0.54-1.45) Emp. 20-<30 yrs. 1.07 (0.79-1.43) **Emp. ≥ 30 yrs. 1.53 (1.06-2.15)**	1.02 (0.80-1.28)[3]	—
3: (Pukkala et al., 2014)	—	—	1.09 (0.91-1.30)	—
5: (Amadeo et al., 2015)	—	—	1.15 (0.77-1.65)	—
6: (Glass et al., 2016)	—	—	0.99 (0.68-1.39)	—
7: (Ahn et al., 2012)	—	—	0.93 (0.76-1.13)[4] 1.09 (0.53-2.25)[5]	Emp. < 10 yrs. 0.98 (0.66-1.41) Emp. ≥ 10 yrs. 0.92 (0.72-1.14)
8: (Ahn and Jeong, 2015)	0.63 (0.43-0.88)	Emp. < 10 Yrs. 0.89 (0.44-1.59) Emp. 10-20 Yrs. 0.50 (0.23-0.95) Emp. ≥ 20 Yrs. 0.60 (0.33-1.00)	—	—
9: (Kang et al., 2008)	—	—	**SMOR** 0.83 (0.53-1.29)[7] 0.97 (0.69-1.35)[6]	—
10: (Bates, 2007)	—	—	1.31 (0.75-2.99)[8] 0.64 (0.30-1.36)[9]	—
11: (Tsai et al., 2015)	—	—	0.81 (0.59-1.11)	—

— Analysis not part of objectives or not shown; Ff = Firefighter
Superscripts beside data indicate the following:
[1] compared to local state populations; [2] compared to US population; [3] restricted to 1st cancers; [4] compared to Korean population; [5] compared to other Emergency responders; [6] compared to all other occupation; [7] compared to police; [8] compared to all other cancers; [9] compared to selected cancers (excluding those potentially related to firefighting)

4.19 Testes

Data on the relevant results for testis cancer risk in the studies considered in section 1 is shown in Table 20 below. Risk of male reproductive cancers overall was significantly increased in firefighters in one cohort study while the excess of prostate cancer alone (RR = 1.31) remained significant, the RR of a similar magnitude (RR = 1.25) for testes was not, perhaps because the statistical power for this much rarer outcome is necessarily much reduced (Glass et al., 2016) (Study 6). The two other cohort studies which reported a result did not show any indication of excess, whether significant or not (Daniels et al., 2014; Pukkala et al., 2014). A case-control study also reported an excess of testis cancer based on 70 firefighters (Bates, 2007) (Study 10) but this was not reproduced in the larger study (Tsai et al., 2015) (Study 11) from the same cancer registry whose 85 cases must have included these 70. The authors of the latter study did not offer an explanation; stating that “No cancers were significantly elevated in Bates and not in our study”.

Review of all other retrieved case-control studies of occupation and testis cancer did not find any mention of firefighters or identify any association between testis cancer and occupation of firefighter.

Conclusion

A significant association in one study from this review, which is increased by removing potentially confounding cancer types from the comparator group, contrasts with lack of any association in the five other studies reporting this cancer. The lack of a plausible mechanism contributes to the conclusion from the current review that there is **no convincing new evidence** of an association between occupation of firefighter and testis cancer. This conclusion is in contrast to the overall results of a meta-analysis performed by IARC in a previous review which showed a 50% excess, based upon 6 studies and approximately 150 cases (IARC, 2010a). Four cohort studies reviewed by IARC had risk estimates ranging from 1.2 to 2.5, although only one was statistically significant; a case-control study gave ORs of 1.5 to 4.3. One study showed a trend between duration of exposure and risk.

Table 20: Summary of data on testis cancer in firefighters

	Mortality		Incidence	
Study number and Reference	**All firefighters (SMR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**	**All firefighters (SIR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**
1:(Daniels et al., 2014)	0.73 (0.15-2.14)	—	0.79 (0.44-1.30)[3]	—
3: (Pukkala et al., 2014)	—	—	0.51 (0.23-0.98)	—
6: (Glass et al., 2016)	—	—	1.25 (0.91-1.69)	—
9: (Kang et al., 2008)	—	—	**SMOR** 1.53 (0.75-3.14)[7] 1.48 (0.88-2.48)[6]	—
10: (Bates, 2007)	—	—	**1.34 (1.04-1.74)[8]** **1.54 (1.18-2.02)[9]**	—
11: (Tsai et al., 2015)	—	—	1.10 (0.73-1.66)	—

— Analysis not part of objectives or not shown; Ff = Firefighter
Superscripts beside data indicate the following:
[1] compared to local state populations; [2] compared to US population; [3] restricted to 1st cancers; [4] compared to Korean population;
[5] compared to other Emergency responders; [6] compared to all other occupation; [7] compared to police; [8] compared to all other cancers; [9] compared to selected cancers (excluding those potentially related to firefighting)

4.20 Thyroid

Data on the relevant results for thyroid cancer risk in the studies considered in section 1 is shown in Table 21 below. Although an excess of thyroid cancer (TC) has been reported for emergency responders from post 9/11 studies none of the studies in firefighters identified an association with thyroid cancer. A doctoral dissertation exploring an explanation for increasing rates of thyroid cancer generally concluded that “incidental detection of TC may be contributing to the increasing incidence and possibly exposure to low-dose radiation from diagnostic procedures as well” (Zeig-Owens, 2015).

Only one relevant case-control study of thyroid cancer was identified, and this made no reference to firefighters.

Conclusion

Taking account of the all of the studies retrieved in this review, it is concluded that there is **no new evidence for an association** between thyroid cancer and the occupation of firefighter.

Table 21: Summary of data on thyroid cancer in firefighters

	Mortality		Incidence	
Study number and Reference	**All firefighters (SMR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**	**All firefighters (SIR, RR or OR)**	**Exposure subgroups (SMR, RR or OR) unless stated otherwise**
3: (Pukkala et al., 2014)	—	—	1.28 (0.75-2.05)	—
6: (Glass et al., 2016)	—	—	1.20 (0.74-1.86)	—
7: (Ahn et al., 2012)	—	—	1.00 (0.60-1.56)[4] 2.17 (0.29-16.51)[5]	Emp. < 10 yrs. 1.21 (0.55-2.29) Emp. ≥ 10 yrs. 0.86 (0.41-1.59)
9: (Kang et al., 2008)	—	—	**SMOR** 0.71 (0.30-1.70)[7] 0.81 (0.41-1.59)[6]	—
10: (Bates, 2007)	—	—	1.06 (0.75-1.51)[8] 1.17 (0.82-1.67)[9]	—
11: (Tsai et al., 2015)	—	—	1.27 (0.88-1.84)	—

— Analysis not part of objectives or not shown; Ff = Firefighter
Superscripts beside data indicate the following:
[1] compared to local state populations; [2] compared to US population; [3] restricted to 1st cancers; [4] compared to Korean population;
[5] compared to other Emergency responders; [6] compared to all other occupation; [7] compared to police; [8] compared to all other cancers; [9] compared to selected cancers (excluding those potentially related to firefighting)

5. SUMMARY OF CONCLUSIONS ON THE LIKELY CANCER RISK TO FIREFIGHTERS

The preceding review has considered the latest evidence from epidemiological data for association between cancer risk and occupation of firefighter at all those sites which have previously been indicated as having a possible association.

Considering possible exposures to carcinogenic substances and taking account of strengths and weaknesses of individual studies, the review cannot formally conclude on a causative link between occupation as a firefighter and any specific cancer type. However, from the evidence reviewed, it is considered that cancer at several locations is identified by studies, both past and recent, as occurring in firefighters more frequently than might be expected. The fact that such differences do not show up in all studies may be due, in part, to weaknesses in the study designs, such as the definition of occupation and the population used as a comparator. However, those same weaknesses may also show differences where none exist.

The increased frequency of cancer types, typically associated with exposures known to occur in firefighters, leads to the conclusion that a causative link between those cancers and occupation cannot be excluded. The available data for each cancer type are insufficient to support a statement of negative association with the occupation of firefighting.

The conclusions of the review by cancer type are detailed below and summarised in Table 22.

Bladder - It is considered that the occupation of firefighter may be associated with an increased risk of bladder cancer, although the degree of statistical association is classified as **limited**. Since there is no strong evidence for a potential causative factor in firefighters' exposure, and studies with more refined analysis and more appropriate comparator populations showed no associations, the evidence is regarded as **weak**.

Bone - There was only one mention of a possible association in all of the data reviewed thus the data retrieved in this review provided no new evidence for an association between the occupation of firefighter and the risk of bone cancer.

Breast (in men) - The data retrieved in this review provided no new evidence for an association between the occupation of firefighter and the risk of breast cancer in men.

Brain - The statistical association of brain cancer with the occupation of firefighter is classified as **mixed**, based on the approach used for this study, since three studies showed a statistically significant association. Firefighters are also known to be exposed to substances which could be linked to brain cancer. However, since none of the cohort studies have confirmed this association, the overall evidence from the new data is considered to be **weak**.

Colorectal - The degree of statistical association of occupation of firefighter with colorectal cancer is concluded to be **mixed**. This is reinforced by the knowledge that firefighters may be exposed to substances, such as polychlorinated biphenyls, which have been linked to rectal cancer. However, considering particularly the lack of any exposure-related association, in those studies where such evidence was obtained, the evidence for association from these new data is considered to be **very weak**.

Head & Neck (including larynx, pharynx and nasopharynx) - The degree of statistical association of head and neck cancer with the occupation of firefighter is classified as **limited**, based on the statistically significant relative risk seen in two studies and the absence of any evidence in the remaining studies. The known association between PAH exposure and cancer at this site, and the evidence of a possible association with length of employment in one study but no evidence from four other studies, mean that the balance of evidence from the new data is considered to be **weak**.

Kidney - The degree of statistical association of renal cancer with occupation of firefighter is classified as **limited**. The new data shows only limited evidence of increased exposure-related incidence in those studies where this was studied. On balance, the evidence for association from the new data is considered to be **weak-moderate**.

Leukaemia (all types) - The degree of statistical association of leukaemia with occupation of firefighter is concluded to be **limited**, based on these new data. The evidence for association in the new data is considered to be **weak**, due in part to the limited evidence for increased relative risk with increased exposure and in part, to the effects in one study being related to more general lympho-haematopoietic cancer rather than leukaemia.

Lung - Overall, the data is concluded to be consistent with the classification of **mixed** for the degree of statistical association of lung cancer with occupation of firefighter. Although the evidence is generally rather weak, the link of lung cancer with asbestos exposure and the limited evidence of some dose-response relationship with firefighting has been considered sufficient to justify a classification of **weak-moderate** for the quality of evidence.

Mesothelioma - Taking account of all the data retrieved in this review it is concluded that an association between mesothelioma and the occupation of firefighter is shown **consistently** by the only studies capable of demonstrating this association. The association of asbestos exposure with the development of mesothelioma is well established within the clinical and scientific literature and is usually indicative of asbestos exposure. The quality of evidence for the association is also considered to be **strong**.

Multiple myeloma - On the basis of the classification system used, the degree of statistical association of this cancer with occupation of firefighter is **limited**. Since there are no known substances in the exposure profile of firefighters which are associated with this type of cancer, and the evidence is extremely limited, the quality of the evidence is concluded to be **very weak**.

Non-Hodgkin lymphoma - The association between the occupation of firefighter and NHL is found in five of eight studies identified in the current review. As a result, the degree of statistical association is classified as **mixed**. The classification of the evidence for the association is concluded to be **moderate**.

Oesophagus - Based on the classification scheme applied in this review, the degree of statistical association between this cancer and occupation of firefighter is **mixed.** One study showing an association with duration of employment cannot be ignored; however, the lack of known causative agents in the exposures experienced by firefighters and the inconsistent pattern of findings in the studies reviewed mean that the evidence for such an association is generally **weak**.

Pancreas - None of the studies retrieved in this review showed any evidence of association of pancreatic cancer with occupation of firefighter. There is also no evidence for any chemical exposures experienced in firefighting which might be associated with pancreatic cancer. Thus, the current review provides **no evidence** for this association.

Prostate - The degree of statistical association of prostate cancer with occupation of firefighter is **mixed.** The quality of evidence for an association of occupation with prostate cancer is not totally consistent from the new studies retrieved, but overall is considered to be of **moderate** strength.

Skin - The degree of statistical association for melanoma skin cancer with occupation of firefighter is classified as **mixed** while that for non-melanoma is considered **limited**. Although melanoma skin cancer is reproducibly associated with the occupation of firefighter, the mechanism of this association is unclear but may be due to polychlorinated biphenyl exposure. The strength of available evidence is considered to be **weak-moderate**. The one study showing an association with non-melanoma skin cancer cannot be ignored since a potential mechanism is known, but the evidence is **very weak**.

Small Intestine - Taking account of all the evidence from the studies retrieved in this review, it is concluded that there is no solid new evidence for an association between cancer of the small intestine and the occupation of firefighter.

Stomach - The isolated significant finding identified in this review cannot be entirely ignored but in the context of eight other studies showing no association, it is concluded that it is insufficient to be considered as new evidence for an association between firefighting and stomach cancer.

Testes - A significant association in one study from this review, which is increased by removing potentially confounding cancer types from the comparator group, contrasts with lack of any association in the four other studies reporting this cancer. The lack of a plausible mechanism contributes to the conclusion from the current review that there is no convincing new evidence of an association between occupation of firefighter and testis cancer.

Thyroid - Taking account of all the studies retrieved in this review, it is concluded that there is no new evidence for an association between thyroid cancer and the occupation of firefighter.

Table 22: Summary of conclusions on cancer and firefighters

Site	Degree of statistical association	Quality of evidence for association	Chemical exposure association (IARC)†	Previous IARC conclusion (IARC, 2010a)
Bladder	**Limited**	**Weak**	Arsenic	
Bone	**None**			
Breast (in men)	**None**			
Brain	**Mixed**	**Weak**	None identified	Not confirmed*
Colon/rectum (large intestine)	**Mixed**	**Very weak**	None identified	Not confirmed*
Head & neck (including larynx and pharynx)	**Limited**	**Weak**	Asbestos, Formaldehyde, Nickel	
Kidney	**Mixed**	**Weak-moderate**	Trichlorethylene	
Leukaemia – all types	**Limited**	**Weak**	Benzene, 1,3-Butadiene	
Lung	**Mixed**	**Weak-moderate**	Asbestos	
Mesothelioma	**Consistent**	**Strong**	Asbestos	
Multiple myeloma	**Limited**	**Very weak**	Benzene	Not confirmed*
Non-Hodgkin lymphoma (NHL)	**Mixed**	**Moderate**	Benzene, Trichloroethylene, Formaldehyde	Possible (approximately 20% excess)
Oesophagus	**Mixed**	**Weak**	None identified	
Pancreas	**None**			
Prostate	**Mixed**	**Moderate**	None identified	Possible (approximately 30% excess)
Skin – melanoma	**Mixed**	**Weak-moderate**	Polychlorinated biphenyls	Not confirmed*
Skin – non-melanoma	**Limited**	**Very weak**	Soot	Not confirmed*
Small intestine	**None**			
Stomach	**None**			Not confirmed*
Testes	**None**			Possible (approximately 50% excess)
Thyroid	**None**			

*Site indicated by meta-analysis (LeMasters et al., 2006), but not confirmed by IARC

†Based on list updated January 2017: http://monographs.iarc.fr/ENG/Classification/Table4.pdf

Note: No data are available on cancer latency specific to firefighters thus a latency of >10 years is assumed for most cancers while for lung cancer a period of >20 years and for mesothelioma a period of >30 years are consistent with Internationally agreed figures, although mesothelioma has occasionally occurred after a shorter period.

5.1 Limitations of the current review

The review, as defined in the introduction and methodology, has been restricted to new epidemiological data published since the review by IARC in 2007. Although the broad conclusions of IARC are considered in discussing the results there was no opportunity to integrate the details from studies reviewed by IARC into the overall analysis. For some cancers where the new data are quite limited, a combined approach such as a meta-analysis might lead to a stronger conclusion about the degree of statistical association.

Most of the studies available use comparison of risk in firefighters with that for the general population; this is likely to underestimate risks as the general population generally presents poorer health indicators than working populations. Comparison with risk in other working groups in emergency services would be more likely to provide a convincing assessment.

The evidence for a link between employment as a firefighter and the various cancers identified is limited in part by the quality of the available studies and particularly by the lack of availability of comprehensive data on specific exposures for each firefighter. The comparison of studies from different populations must make assumptions of similarity of exposures for all firefighters, without a sound evidence base. A few studies which have used various surrogates for exposure may be notionally of greater value but even for these, the data are very much an approximation.

Data on exposure of firefighters to risk factors in other employments either prior or contemporary with their firefighting role is generally not available and thus cannot be included in any analysis.

Given the limited number of relevant publications identified, the evidence is in some cases very limited and often dependent upon studies with very small populations or incidences of the relevant cancers. In such instances, the only possible conclusion of this review is that there is a lack of additional evidence for occupational association of cancer.

Although every effort has been taken to address confounding factors in the analysis, this is only possible by using the published data. In many cases, the information available from the publication is insufficient, thus the final conclusions are made in a way which does not attempt to quantify these factors. If it is possible that bias may exist in the results, the interpretation of the data and conclusions have been made in such a way that potential associations are not excluded.

5.2 Relevant cancer risk for firefighters

Based upon the current review there is the strongest evidence for an excess of mesothelioma for those who were employed as a firefighter more than 30 years ago, probably as result of asbestos exposure. Lung cancer is not as strongly associated but is known to be linked to the same exposures, so cannot be ruled out as occupationally related.

There is no conclusive evidence for association of any other cancer type with the occupation of firefighter, however, NHL and prostate cancers have been found more frequently in firefighters in both the current review and in that made previously by IARC (IARC, 2010a)

The current review could not rule out the possibility of an association between occupation of firefighter and cancers of bladder, brain, colon/rectum, head & neck, kidney, oesophagus and skin, together with leukaemia and multiple myeloma.

Cancer at some of these sites (brain, colon/rectum, skin) has been indicated as potentially linked to occupation of firefighter by another analysis (LeMasters et al., 2006); however, the review by IARC (IARC, 2010a) considered that analysis and did not find sufficient evidence to support that conclusion.

The occupational association with cancer at the other sites identified in this review (bladder, head & neck, kidney, oesophagus, multiple myeloma and leukaemia) is not supported by the previous reviews thus no further conclusion can be drawn.

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ANNEX 1 – DETAILED LITERATURE SEARCH STRATEGY

A) CANCER AND POMPIERS AND RISQUE

CANCER
Cancer*
Carcinogenesis
Metastasis
Mesothelioma
Neoplasm*
Tumor*
Neoplasms[MESH]
Neoplasm[SH]
Tumeur

POMPIERS
firefighter
fire fighter
Firefighters[MESH]
fireman
firemen
Pompier
sapeur-pompier
sapeur pompier

RISQUE
epidemiologic
Epidemiological
epidemiology
Incidence
Mortalité
Mortality
Risk
Risque
Epidemiologic Studies[MESH]
Epidemiologic Methods[MESH]
epidemiology[SubHeading]
mortality [Subheading]
Risk factors[MESH]

B) RÉGION ANATOMIQUE AND CANCER AND RISQUE AND SST

RÉGIONS ANATOMIQUES
B1
Kidney
Rein
Reins
Renal
Kidney Neoplasms[MESH]

B2
Urinary bladder
Bladder
Vessie
Urinary Bladder[MESH]
Urinary Bladder Neoplasms[MESH]

B3
Esophagus
Gullet
Oesophage
Œsophage
Oesophagus
Œsophagus
Esophagus[MESH]
Esophageal Neoplasms[MESH]

B4
Lymphome non hodgkinien
Non hodgkin lymphoma*
Non-hodgkin lymphoma*
Non-hodgkin's lymphoma
Lymphoma, Non-Hodgkin[MESH]

B5
Leucaemia*
Leucemia*
Leucémie*
Leukaemia*
Leukemia*
Leukemias
Leucocythaemia*
Leucocythemia*
Leukemia[MESH]

B6
Lung*
Poumon*
Pulmonaire*
Pulmonary
Lung[MESH]
Lung Neoplasms[MESH]

B7
Mésothéliome
Mesothelioma
Mesothelioma[MESH]

B8
Bouche
Buccal
Cou
Gorge
Head and Neck Neoplasms[MESH]
Head[MESH]
Mouth
Mouth Neoplasms[MESH]
Mouth[MESH]
Neck[MESH]
Oral
Oropharyngeal
Oropharyngeal Neoplasms[MESH]
Oropharynx
Oropharynx[MESH]
Oropharynxs
Paranasal Sinus Neoplasms[MESH]
Paranasal Sinuses[MESH]
Pharyngeal
Pharyngeal Neoplasms[MESH]
Pharynx
Pharynx[MESH]
Pharynxs
Sinus
Sinuses
Tête
Throat
Throats

B9
Colorectal
Colon
Colonic
Intestinal
Intestine
Rectum
Rectal
Colorectal Neoplasms[MESH]
Intestine, Large[MESH]

B10
Breast AND male
Breast Neoplasms[MESH]
Breast Neoplasms, Male[MESH]

B11
Prostate
Prostatic
Prostatic Neoplasms[MESH]

B12
Pancreas
Pancreas[MESH]
Pancreatic
Pancreatic Neoplasms[MESH]

B13
Skin
Skin[MESH]
Skin Neoplasms[MESH]

B14
Thyroid
Thyroid Gland[MESH]
Thyroid Neoplasms[MESH]

B15
Testes
Testis
Testis[MESH]
Testicular
Testicular Neoplasms[MESH]

B16
Bone
Bone and Bones[MESH]
Bones
Os
Bone Neoplasms[MESH]

B17
Laryngeal
Larynx
Laryngeal Neoplasms[MESH]

B18
Kahler Disease
Multiple myeloma
Multiple Myeloma[MESH]
Multiple Myelomas
Myelomatoses
Myelomatosis
Plasma-Cell Myeloma
Plasma-Cell Myelomas

B19

Gastric
Stomach
Stomach[MESH]
Stomach Neoplasms[MESH]

B20
Brain
Brain[MESH]
Brains
Cerveau
Encephalon
Encephalons
Brain Neoplasms[MESH]

[B21]
Small intestine
Small Intestines
Intestine, Small[MESH]
Intestinal Neoplasms[MESH]

[B22]
Ureter
Ureter[MESH]
Ureters
Ureteral
Ureteral Neoplasms[MESH]

CANCER
Cancer*
Carcinogenesis
Metastasis
Mesothelioma
Neoplasm*
Tumor*
Neoplasms[MESH]
Neoplasm[SH]
Tumeur

RISQUE
epidemiologic
Epidemiological
epidemiology
Incidence
Mortalité
Mortality
Risk
Risque
Epidemiologic Studies[MESH]
Epidemiologic Methods[MESH]
epidemiology[SubHeading]
Risk factors[MeSH]
mortality [Subheading]

SST
Employee
Employees
Employment
Employment[MESH]
Manpower[Subheading]
Occupation
Occupational
Occupational Diseases[MESH]
Occupational Exposure[MeSH]
Occupational Health[MESH]
Personnel
Staff
Travail
travailleur*
Worker
Workers
Workload[MeSH]
Workman
Workmen
Workplace
Workplace[MESH]
Worksit

ANNEX 2 – CRITERIA OF THE MODIFIED NEWCASTLE-OTTAWA ASSESSMENT SCALE APPLIED TO COHORT AND CASE-CONTROL STUDIES

NEWCASTLE - OTTAWA QUALITY ASSESSMENT SCALE with *annotation (in italics),* commentary and new criteria added by report authors (in blue).

COHORT STUDIES

Note: In the original scheme a study can be awarded a maximum of one star for each numbered item within the Selection and Outcome categories, and a maximum of two stars can be given for Comparability, with a maximum of 10 stars in total*.*
The maximum number of stars for cohort studies using additional criteria is 12 for all studies and 13 for those with some exposure classification.

Selection

1) Representativeness of the exposed cohort
   a) truly representative of the average *employed firefighter* in the community ★
   b) somewhat representative of the average *employed firefighter* in the community ★
   c) selected group (firefighters)
   d) no description of the derivation of the cohort
2) Selection of the non-exposed cohort
   a) drawn from the same community as the exposed cohort (*i.e. subject to the same selection forces as the exposed cohort*) ★
   b) drawn from a different source (*e.g. general population, who are not all employed)*
   c) no description of the derivation of the non-exposed cohort
3) This item in the Newcastle-Ottawa scale is moved to end of Cohort studies section
4) Demonstration that outcome of interest was not present at start of study
   a) yes ★
   b) no

This criterion follows the principle that a cohort study should not include prevalent cases. However, in the long follow-up periods typical of occupational cohort studies, failure to meet this criterion is unlikely to lead to any important bias, provided that the same method for case counting applies to exposed and unexposed.

Criterion is necessarily true in mortality studies which start with living people.

Have assumed that criterion is met in morbidity studies restricted to primary cancers, diagnosed after date of entry.

Comparability

1) Comparability of cohorts on the basis of the design or analysis
   a) study controls for the most important factor. Factors selected: *age and gender*. ★
   b) study controls for any additional factor or a second important risk factor. Factor selected*: smoking.* ★

To add further discrimination, we have added:

c) socioeconomic status or BMI ★
d) ethnicity ★★★
e) geographical adjustment ★★ *(In studies which compared firefighters with the national population, assume true if exposed group covers > 90% of firefighters in the country)*

Since risk factors vary by cancer site, simple rules are not really adequate for studies which examine multiple cancer sites; e.g. smoking is not relevant to some cancers. Nevertheless, we have rated the study, as a whole, on these factors.

Level of proof: where there is adequate adjustment by statistical analysis or the authors persuade that the risk factor is not very different between groups, then the criterion is met.

Outcome

1) Assessment of outcome
   a) independent blind assessment ★
   b) record linkage ★
   c) self-report
   d) no description
2) Was follow-up long enough for outcomes to occur
   a) yes *(> 10 years)* ★
   b) no

10 years may not be enough in a young cohort; we also give the number of cancers among firefighters as a simple indicator of study size/power

3) Adequacy of follow up of cohorts
   a) complete follow up - all subjects accounted for ★
   b) subjects lost to follow up unlikely to introduce bias - small number lost, *i.e. 95%* follow up, or description provided of those lost ★
   c) follow up rate < *95%* and no description of those lost
   d) no statement

Where follow-up is through national registries, the ascertainment rates of the registry are key here.

We have added the following section which includes point 3 from the original Selection section, which logically belongs here:

Exposure Assessment

1) Scale used to classify exposed cohort by degree of exposure
   a) number of fireruns, fire-hours, incidents, or similar ★
   b) duration of employment ★
   c) none: study does not divide exposed group into subcategories

2) Ascertainment (*reliability*) of exposure

   a) secure record *(e.g. employment records*) ★
   b) structured interview *before outcome is measured* ★
   c) written self-report
   d) no description
   e) not applicable

Referring to the reliability of exposure assessment, it assumes that there has been some classification of the exposed cohort into sub-categories. The rating 'not applicable' should be given for studies which do not attempt this.

CASE CONTROL STUDIES

Note: Under the original scheme a study can be awarded a maximum of one star for each numbered item within the Selection and Outcome categories, and a maximum of two stars can be given for Comparability, with a maximum of 10 stars in total. The maximum number of stars for case-control studies using additional criteria is 13.

Selection

1) Is the case definition adequate?
   a) yes, with independent validation *e.g.* >1 person/record/time/process to extract information OR reference to primary record source such as x-rays or medical/hospital records *or cancer registry* ★
   b) yes, record linkage or based on self-reports.
   c) no description
2) Representativeness of the cases
   a) consecutive or obviously representative series of cases ★
   b) potential for selection biases or not stated
3) Selection of Controls

This item assesses whether the control series used in the study is derived from the same population as the cases and essentially would have been cases had the outcome under study been present.

   a) community controls (*i.e.* same community as cases and would be cases if had outcome) ★
   b) hospital controls (*i.e.* within same community as cases, not another city, but derived from a hospitalised population)
   c) no description

Controls chosen from a cancer registry almost certainly would have been cases had the outcome under study been present; as such they meet the essence of the criteria. We consider this choice as valid (Miettinen and Wang, 1981) under the restriction as follows:

   d) *Where cases are from a cancer registry, controls are from the same cancer registry and the control cancers are not causally linked to firefighting.* ★

4) Definition of Controls
   a) no history of relevant cancer ★
   b) no mention of history of outcome

Comparability

This section is identical to that for cohort studies (up to 5 stars).

Exposure

1) Ascertainment of exposure

   a) secure record (*e.g. employment record, hospital records, registry forms*) ★
   b) structured interview where blind to case/control status ★
   c) interview not blinded to case/control status
   d) written self-report or medical record only
   e) no description

This criterion is applicable to all case-control studies, as it can be applied, even to methods used to classify as simply Firefighter (Yes/No). We have added additional criteria below to rate any further exposure scale.

2) Same method of ascertainment for cases and controls

   a) yes ★
   b) no

3) Non-Response rate

   a) same rate for both groups ★
   b) non-respondents described
   c) rate different and no designation

Non-response should be interpreted in the sense of any exclusion of the intended participants. In studies based entirely on records, this includes a restriction because of missing information: for example, no information given in records about occupation.

We have added the following which allow studies with further exposure assessment to be differentiated:

4) Scale used to classify firefighters by degree of exposure

   a) number of fire-runs, fire-hours, incidents, or similar ★
   b) high/medium/low categories inferred from employment history by expert(s) ★
   c) duration of employment ★
   d) none: study does not divide exposed group into subcategories

It is assumed that information used for the exposure scale in 4) is the same as in 1) and so no further stars are awarded for its quality

ANNEX 3 – DETAILED NEWCASTLE-OTTAWA SCORES GIVEN TO THE KEY STUDIES OF CANCER IN FIREFIGHTERS

	Cohort study number and details							
	1 US	**2 US**	**3 Nordic**	**4 Scot-land**	**5 France**	**6 Australia**	**7 Korea**	**8 Korea**
	(San Francisco + Chicago + Philadelphia) 1950-2009 Morbidity + Mortality	(San Francisco + Chicago + Philadelphia) 1950-2009 Morbidity + Mortality	Morbidity		Morbidity	Morbidity + Mortality	1996-2007 Morbidity	1992-2007 Mortality
Selection								
S1	*	*	*	*	*	*	*	*
S2	-	-	-	-	-	-	*[1]	*[1]
S4	*	*	*(p)	-	*	*	-	-
Comparability								
C1 (age)	*	*	*	-	*	*	*	*
C2 (smoking)	-	-	-	-	-	-	*[1]	*[1]
C3 BMI/SE status	-	-	-	-	-	-	*[1]	*[1]
C4 ethnicity	*	*		-	-	-	-	-
C5 geography	-[3]	*[4]	*	*	*	-	*	*
Outcome								
O1	*	*	*	-	*	*	*	*
O2	*	*	*	*	*	*	-[2]	*
O3	*	*	*	-	*	*	*	*
Exposure								
E1	*	*	-	-	-	*	-	*
E2 (Newcastle-Ottawa S3); possibly N/A	*	*	na	na	na	*	na	*
Total no. of FF cancers	4,461	2,609	2,653	39	749	1,693	446	167

p=partial: met for 2/5 countries; na = not appropriate; FF = Firefighter

[1]: For comparisons with non-firefighter ERs only; not true for comparisons with General Population

[2]: Mean PY of follow-up = 9.4 yrs.; mean duration of employment was 15.2 yrs.

[3]: Comparisons with local state data only in online Supplementary Table S8

[4]: Fire Dept. included in regression models

	Case-control study number and details		
	9 **US**	**10** **US**	**11** **US**
	Massachusetts 1987-2003	California 1988-2003	California 1988-2007
Selection			
S1	*	*	*
S2	*	*	*
S3	-[1]	-[2]	*[3]
S4	-	-	*
Comparability			
C1 age	*	*	*
C2 smoking	*		-
C3 BMI/SE status	-	*	-
C4 ethnicity	-	*	*
C5 geography	na	na	na
Exposure			
E1	*	*	*
E2	*	*	*
E3	-	-	-
E4	-	-	-
E5	na	na	na
Total no. of FF cancers	2,125	3,659	3,996

na = Not appropriate; FF=Firefighter
[1]: Control cancers include mesothelioma.
[2]: Data-dependent method for choosing control cancers may have led to bias
[3]: Control cancers - pharynx, stomach, liver and pancreas – are valid choice if no causal relationship with FF

ANNEX 4 – REJECTED PAPERS

Bladder		
Audureau, E., et al. (2007)	Based on 258 cases of bladder cancer the associations with occupational exposures did not cite any aspect which related to firefighters.	Rejected - no relevance to firefighters
Baan, R., et al. (2008)	Brief pre-notification of IARC conclusions on carcinogenicity of aromatic amines, organic dyes and related exposures. Firefighters are not mentioned	Rejected - no relevance to firefighters
Bachand, A., et al. (2010)	meta-analysis of painting and bladder cancer no mention of firefighters	Rejected - no relevance to firefighters
Burger, M., et al. (2013)	Review of risk factors for urothelial bladder cancer. No mention of PAH or firefighters.	Rejected - no relevance to firefighters
Carreón, T., et al. (2013)	Bladder cancer risk associated with exposure to three chemicals no mention of firefighters.	Rejected - no relevance to firefighters
Cassidy, A., et al. (2009)	A US study of 604 cases of urinary bladder cancer compared with cancer-free controls matched for age, gender and ethnicity showed a number of occupations with a significantly higher OR for bladder cancer but there was no mention among the occupations listed of firefighters or any other category that might be used as substitute for firefighters	Rejected - no relevance to firefighters
Colt, J. S., et al. (2011)	Among 1,158 patients newly diagnosed with bladder cancer in New England there was an excess of those who declared their occupation as metalworkers or plastic workers. The report listed various occupations with significant excess of bladder cancer but did not mention firefighters as a category in any context.	Rejected - no relevance to firefighters
Dryson, E., et al. (2008)	A New Zealand study of 213 bladder cancer cases notified between 2003 and 2004 used 471 controls randomly selected from the electoral roll, matched by age. Apart from hairdressers there was no occupation showing an excess of bladder cancer. Firefighters were not listed as an occupation in this study	Rejected - no relevance to firefighters
Erdurak, K., et al. (2014)	Comparison of 173 bladder cancer cases in Manisa Turkey, with 282 controls matched by age, sex, location, concentrated on the connection with smoking and identified no novel associations with occupation.	Rejected - no relevance to firefighters
Ferreccio, C., et al. (2013)	Association between specific occupational exposures and bladder cancer risk no mention of firefighters.	Rejected - no relevance to firefighters
Ferris, J., et al. (2013)	Review of occupational origin of bladder cancer mentions firefighters but provides no supporting evidence or data.	Review no new data. Rejected - no relevance to firefighters
Figueroa, J. D., et al. (2015)	Study of the influence of genetic polymorphism on bladder cancer risk. No mention of firefighters	Rejected - no relevance to firefighters
Geller, F., et al. (2008)	A German study examined occupational profiles of chemical exposure by questionnaire for 156 bladder cancer patients and compared them with 336 prostate cancer patients. A significant excess of bladder cancer was seen for those exposed to paints, bitumen and tar but no association was made which was relevant for firefighters.	Rejected - no relevance to firefighters
Kellen, E., et al. (2007)	Association between Cadmium exposure and bladder cancer no mention of firefighters.	Rejected - no relevance to firefighters
Khoubi, J., et al. (2013)	Three hundred bladder cancer patients in Iran were compared with randomly selected controls without any history of cancer, from the same region as the cases. A significant excess of bladder cancer was found for housekeepers, agricultural, building and metal workers as well as truck and bus drivers but no mention was made of firefighters.	Rejected - no relevance to firefighters

Kiriluk, K. J., et al. (2012)	Review no new data.	Rejected - no relevance to firefighters
Kobeissi, L. H., et al. (2013)	Study is examining a range of associations with bladder cancer risk including socio-economic and smoking but does not mention occupational and does not mention firefighters	Rejected - no relevance to firefighters
Pecoux, F., et al. (2011)	This case-control study from France was based on 69 patients of whom 37 had been exposed to occupational carcinogens. Firefighters are not represented in the occupations listed.	Rejected - no relevance to firefighters
Porru, S., et al. (2014)	A hospital-based case-control study of bladder cancer (201 cases) examining mainly smoking but also taking account of various other exposures. No mention of firefighters or relevant exposures.	Rejected - no relevance to firefighters
Reulen, R. C., et al. (2007)	A Belgian study of 202 bladder cancer cases compared with 390 randomly selected controls with no history of bladder cancer did not classify firefighters as an occupation but a category of personal and protective service workers had an OR of 1.1 (0.4-2.8).	Rejected - no relevance to firefighters
Samanic, C. M., et al. (2008)	A total of 1,219 Spanish bladder cancer patients were compared with 1,465 controls selected from patients admitted to the same hospital for diseases/conditions unrelated to bladder cancer. Despite listing > 50 occupations firefighter was not mentioned and thus must be assumed not to be associated with bladder cancer risk for this study.	Rejected - no relevance to firefighters
Scarselli, A., et al. (2011)	A study looking primarily at bladder cancer risk in manufacturing industry by comparing white-collar workers with blue-collar workers. No mention of firefighters	Rejected - no relevance to firefighters
Scarselli, A., et al. (2009)	Publication very similar to another by the same authors and making no reference to firefighters.	Rejected - no relevance to firefighters
Selinski, S., et al. (2012)	No reference to occupational exposures or firefighters	Rejected - no relevance to firefighters
Shakhssalim, N., et al. (2010)	A further study from Iran reported risk factors for bladder cancer based on 692 cases and 692 controls randomly matched with the patients for age, gender and area of residence. The risk factors identified were mainly lifestyle with very limited occupational analysis which showed no association with cancer cases.	Rejected - no relevance to firefighters
Wang, Y. H., et al. (2009)	Gene - arsenic interaction and no mention of firefighters.	Rejected - no relevance to firefighters
Weistenhofer, W., et al. (2008)	Genetic polymorphism and effect on bladder cancer risk. No mention of firefighters	Rejected - no relevance to firefighters
Bone sinuses		
Bonzini, M., et al. (2013)	A study of the occupation of 73 Italian subjects with sino-nasal cancer concluded that exposure to wood and leather dust was associated with intestinal-type adenocarcinoma while exposure to formaldehyde, solvents and metal fumes was associated with other cancer types including squamous cell carcinoma. Not relevant to firefighters.	Rejected - no relevance to firefighters
Breheret, R., et al. (2011)	Of 42 cases of ethmoid sinus carcinoma in a French study >85% had been exposed to wood dust. The study concentrates on the post diagnostic and post-surgery prognosis.	Rejected - no relevance to firefighters
Magee, B., et al. (2010)	Study considers exposure to Naphthalene and cancer risk. No consideration of firefighters or mention of exposure of firefighters to Naphthalene	Rejected - no relevance to firefighters
Mensi, C., et al. (2010)	Rejected - foreign language paper with no relevant novel data	
Scarselli, A., et al. (2009)	An analysis of compensated occupational cancer claims in Italy between 1994 and 2006 made no mention of cancers associated with firefighters.	Rejected - no relevance to firefighters

Sham, C. L., et al. (2010)	A group of 50 cases of sino-nasal inverted papilloma cases was compared with a control group of 150 cancer cases excluding those with any pathology of the sino-nasal or associated regions and cancers of head and neck. Data on occupation were obtained but numbers were too small for valid conclusions. Firefighters were not mentioned.	Rejected - no relevance to firefighters
Slack, R., et al. (2012)	This review of occupational risks associated with nasopharyngeal and sino-nasal cancer makes no reference to firefighters.	Review no new data. Rejected - no relevance to firefighters
Breast (male)		
VILLENEUVE, S. (2011)	The relevant part of this thesis is a case-control study of male breast cancer and association with occupation. The possible association with motor vehicle mechanics and solvent exposures makes no mention of firefighter or related occupations.	Rejected - no relevance to firefighters
Brain		
Bhatti, P., et al. (2009)	Based on case-control analysis of 496 patients with brain tumours and 494 controls this study investigated genetic polymorphism and lead exposure as causative factors. Firefighters not mentioned.	Rejected - no relevance to firefighters
Bhatti, P., et al. (2011)	Based on case-control analysis of 506 patients with brain tumours and 505 controls this study investigated genetic polymorphism and lead exposure as causative factors. Firefighters not mentioned.	Rejected - no relevance to firefighters
Coureau, G., et al. (2014)	This report is dedicated to the relationship between mobile phone use and brain tumours, thus is not relevant to firefighters.	Rejected - no relevance to firefighters
Gomes, J., et al. (2011)	Duplicate	Rejected - Duplicate
Klaunig, J. E. (2008)	Report of the carcinogenicity of acrylamide which makes no reference to firefighters.	Rejected - no relevance to firefighters
Lacourt, A., et al. (2013)	Large Case-control study (1,800 cases) looking at a range of occupational exposure (diesel and gasoline exhaust emissions, benzo(a)pyrene), dusts (animal dust, asbestos, crystalline silica, wood dust) and relationship with glioma incidence. No mention of firefighters in the results or conclusions	Rejected - no relevance to firefighters
Levis, A. G. (2010)	Rejected - foreign language paper with no relevant novel data	
Mazumdar, M., et al. (2008)	For 202 brain cancer cases in Taiwan compared with 501 controls the study looked for association with occupation both of the subject and of parents. The occupational categories are rather general but make no reference to firefighters or a specifically relevant group.	Rejected - no relevance to firefighters
Neta, G., et al. (2012)	An analysis of chlorinated solvent exposure for 489 brain cancer patients from Arizona, Massachusetts and Pennsylvania compared with 799 controls made no reference to firefighters.	Rejected - no relevance to firefighters
Oddone, E., et al. (2014)	This study is directed solely towards the incidence of brain tumours in steel foundry workers and does not consider any other occupation	Rejected - no relevance to firefighters
Ohgaki, H. (2009)	Review without any new data or analysis	Review no new data. Rejected - no relevance to firefighters
Porter, A. B., et al. (2015)	Study is designed to consider general population risk of glioblastoma related to age and socioeconomic status. No consideration of specific occupations and no mention of firefighters	. Rejected - no relevance to firefighters
Ruder, A. M., et al. (2012)	The study involved 780 glioma patients compared with 1,156 controls for association of occupation with the cancer. Although firefighters are mentioned in the discussion as a potential risk group the study did not specifically generate a relative risk for firefighters and made no mention of them as an occupational category among the patients	Rejected - no relevance to firefighters
Ruder, A. M., et al. (2013)	This study evaluated the chlorinated solvent exposure of 798 brain cancer cases and 1,175 population controls. There was no mention of firefighters	Rejected - no relevance to firefighters

Samkange-Zeeb, F., et al. (2010)	Examination of 844 cases of brain tumour and association with occupation in Germany focussed on 6 occupational categories and did not mention or consider firefighters in the analysis	Rejected - no relevance to firefighters
Spinelli, V., et al. (2010)	A study of 122 brain cancer cases from France compared with an equal number of controls considered a range of occupations where exposure to chlorinated solvents may occur but made no mention of firefighters	Rejected - no relevance to firefighters
Turner, M. C., et al. (2014)	This study is concentrated on the link between low frequency magnetic fields and brain cancer risk thus there is no mention of firefighters	Rejected - no relevance to firefighters
van Tongeren, M., et al. (2013)	Multicentre case-control study of brain cancer and occupational exposure. No mention of firefighters.	Rejected - no relevance to firefighters
van Wijngaarden, E. and M. Dosemeci (2007)	The study was based on the mortality of 317,968 individuals from the US population between 1979 and 1980. For each the occupation and industry were known and used to calculate possible exposure to lead. No specific reference to firefighters.	Rejected - no relevance to firefighters
Van Wijngaarden, E. and M. Dosemeci (2007)	Erratum only	Rejected - no relevance to firefighters
Colorectal		
Almurshed, K. S. (2009)	Case-control study from Egypt of 50 cases of colon cancer. Studied association with dietary habits rather than occupation.	Rejected - no relevance to firefighters
Boyle, T., et al. (2011)	An Australian study of 918 cases of colorectal cancer compared with randomly selected controls. Specific occupational history was analysed only to obtain an index of the sedentary nature of the work.	Rejected - no relevance to firefighters
Grant, W. B. (2014)	This study of UV association with skin cancer mentions nothing relevant to colorectal cancer or firefighters apart from beneficial effects of vitamin D.	Rejected - no relevance to firefighters
Lo, A. C., et al. (2010)	421 Egyptian colorectal cancer patients were compared with 439 hospital-based controls. Although occupational and exposure data were obtained by questionnaire the analysis gives no in-formation on specific occupational associations.	Rejected - no relevance to firefighters
Wang, X. S., et al. (2011)	Rejected - Duplicate	
Head & Neck		
d'Errico, A., et al. (2009)	The occupation of 113 cases of sino-nasal cancer recorded in the Piedmont region of Italy between 1996 and 2000 was compared with that of 336 hospital controls, frequency matched to controls for age, sex and province of residence. Subjects completed a detailed questionnaire in face-to-face interview. Job-exposure matrices were used to estimate potential exposure to a range of risk factors for sino-nasal cancer. Nothing was found relevant to firefighters.	Rejected - no relevance to firefighters
Ekburanawat, W., et al. (2010)	A case-control study of nasopharyngeal cancer from Bangkok, Thailand investigated 327 newly diagnosed cases and compared them with the same number of controls selected from hospital visitors to the same centre. The occupational aspects of the study concentrated on wood-dust exposure and made no mention of firefighters.	Rejected - no relevance to firefighters
Guo, X., et al. (2009)	Study of 1,049 cases of nasopharyngeal cancer from China, compared with 785 controls who were selected from viral screening programmes to be serum positive for antibodies to Epstein-Barr virus. The study investigated lifestyle effects including exposure to domestic wood-burning fires. No relevance to firefighters.	Rejected - no relevance to firefighters
Richiardi, L., et al. (2012)	A study described as the ARCAGE case-control study was conducted between 2000 and 2005 on 1,851 patients from 14 European centres with cancer of oral cavity, oropharynx, hypopharynx, larynx or oesophagus compared with 1,949 controls. Controls were selected differently in different centres but were all frequency matched to cases by age, sex and centre. Firefighters did not feature in the occupations listed in the analysis.	Rejected - no relevance to firefighters

Sartor, S. G., et al. (2007)	Rejected - foreign language paper with no relevant novel data	
Slack, R., et al. (2012)	Duplicate	Rejected - Duplicate
Kidney		
Bernat Garcia, J., et al. (2013)	Study is of kidney transplant patients and there is no mention of firefighters and no relevant exposures	Rejected - no relevance to firefighters
Boffetta, P., et al. (2011)	Relationship between exposure to heavy metals (arsenic, cadmium, lead, chromium) and bladder cancer. No mention of firefighters or relevant exposures to those metals.	Rejected - no relevance to firefighters
Charbotel, B., et al. (2009)	Case-control study of relationship between trichlorethylene (TCE) exposure and renal cancer with suggestions that OELs are too high. No mention of firefighters or exposure to TCE in firefighters.	Rejected - no relevance to firefighters
Chow, W. H., et al. (2010)	Review no new data. Rejected - no relevance to firefighters	
Fear, N. T., et al. (2009)	A UK study of 2,568 cases of Wilm's tumour, an embryonal malignant kidney tumour, compared with 2,568 controls matched by sex, age, and registration district. The data were analysed using the paternal occupation recorded on the birth record. No effect of any paternal occupation was found and firefighters were not mentioned specifically	Rejected - no relevance to firefighters
Karami, S., et al. (2011)		Rejected - no relevance to firefighters
Karami, S., et al. (2008)	Association of renal cancer with pesticide exposure taking account of genetic polymorphisms in glutathione transferase. No mention of firefighters or any exposure which are relevant.	Rejected - no relevance to firefighters
Karami, S., et al. (2010)		Rejected - no relevance to firefighters
Karami, S., et al. (2011)		Rejected - no relevance to firefighters
Mariusdottir, E., et al. (2016)	This study considered the occupational exposure of 225 cases of renal cancer in the Icelandic population and made no mention of firefighters or exposures relevant to firefighters.	Rejected - no relevance to firefighters
McNeil, C. (2013)	Editorial article on renal carcinogenicity of TCE, without any novel data or analysis and no reference to firefighters.	Review no new data. Rejected - no relevance to firefighters
Moore, L. E., et al. (2010)	Study of genetic factors in the risk of renal cancer and TCE exposure. No reference to exposures or occupation of firefighter.	Rejected - no relevance to firefighters
Ng, J. C., et al. (2014)	Study is about organ transplantation and not occupational cancer.	Rejected - no relevance to firefighters
Pisareva, L. F., et al. (2014)	Rejected - foreign language paper with no relevant novel data.	
Sabath, E. and M. L. Robles-Osorio (2012)	The mechanism of heavy metal (cadmium, lead and arsenic) injury to kidney is not linked to occupational cancer by this review	Review no new data
Theis, R. P., et al. (2008)	A case-control study of renal cancer and the association with smoking and with environmental tobacco smoke with no specific mention or relevance to firefighters.	Rejected - no relevance to firefighters
Toyokuni, S. (2014)	Review of the impact of iron overload on asbestos-induced mesothelioma. No specific mention of firefighters.	Review no new data. Rejected - no relevance to firefighters

Wiesenhutter, B., et al. (2007)	A study of genetic polymorphism and renal cancer risk associated with TCE exposures. No mention of firefighters or any relevant exposures.	Rejected - no relevance to firefighters
Yang, H. Y., et al. (2009)	A study of Chinese herbalists and the incidence of renal cancer with a conclusion that there is an increased risk of renal cancer among Chinese herbalists but the study has no relevance or makes no mention of firefighters.	Rejected - no relevance to firefighters
Zils, K., et al. (2008)	This is a review of hospital practice rather than any investigation into renal carcinogenesis thus has no relevance to firefighters or their occupational exposures.	Rejected - no relevance to firefighters
Larynx		
Brown, T., et al. (2012)		Rejected - Duplicate
Cheremisina, O. V., et al. (2015)	Rejected - foreign language paper with no relevant novel data	
Menvielle, G., et al. (2016)	This study was examining the 3-way interaction between asbestos, tobacco and alcohol among 2830 cases of laryngeal cancer in France. Firefighter was not a factor considered in the analysis.	Rejected - no relevance to firefighters
Pasetto, R., et al. (2014)	Study concentrated solely on the effects of asbestos exposure with no reference to firefighters.	Rejected - no relevance to firefighters
Ramroth, H., et al. (2011)	Study concentrated on the effects of asbestos exposure with no reference to firefighters.	Rejected - no relevance to firefighters
Richiardi, L., et al. (2012)	The study included 1,851 patients with incident cancer of the oral cavity, oropharynx, hypopharynx, larynx or oesophagus and 1,949 controls. The analysis for occupation makes no reference to firefighters.	Rejected - no relevance to firefighters
Santi, I., et al. (2014)	Study of 208 cases of laryngeal cancer in Germany considered the occupational associations but made no reference to firefighters.	Rejected - no relevance to firefighters
Sartor, S. G., et al. (2007)	Rejected - Duplicate	
Sturgis, E. M. (2010)	Letter to the editor - no new data.	Rejected - not relevant to firefighters
Leukaemia		
Blair, A., et al. (2007)		Rejected - no relevance to firefighters
Khalade, A., et al. (2010)	Review no new data.	Rejected - no relevance to firefighters
McLean, D., et al. (2009)	The association between leukaemia and occupation was explored in a comparison of 225 New Zealand leukaemia cases compared with 471 randomly selected controls matched by age, Occupational and lifestyle data was obtained by interview. Firefighter was not mentioned or identified as part of any of the occupational groups analysed.	Rejected - no relevance to firefighters
Robinson, C. F., et al. (2015)	This analysis uses occupational codes which are very general. The code relevant to firefighters is protective services but this includes a wide range of occupations and is not further broken down. It allows no conclusions to be drawn concerning the association between occupation of firefighter and leukaemia.	Rejected - no relevance to firefighters
Saberi Hosnijeh, F., et al. (2013)	Within a large European cohort study (EPIC) 477 cases of leukaemia were diagnosed up to 2010. The occupational profile of these cases was compared with that of the remainder of the cohort (240,988). There was no mention of firefighter as an occupation associated with leukaemia.	Rejected - no relevance to firefighters
Sathiakumar, N., et al. (2015)		Rejected - no relevance to firefighters

Sielken, R. L., Jr. and C. Valdez-Flores (2015)	Review no new data.	Rejected - no relevance to firefighters
Talibov, M., et al. (2014)	This study considered solvent exposure in Nordic populations as a risk factor for acute myeloid leukaemia. The study provided no evidence for an association and made no mention of firefighters.	Rejected - no relevance to firefighters
Lung		
Ahn, Y. S. and S. K. Kang (2009)	Relates to asbestos-related cancers in Korea and compensation. No mention of firefighters.	Rejected - no relevance to firefighters
Arakawa, H., et al. (2009)	Report describes an evaluation of diagnostic procedures relative to lung cancer originating from silica exposureThe report makes no attempt to study the association between occupation and the cancer and does not mention firefighters.	Rejected - no relevance to firefighters
Balmes, J. R. (2013)	Editorial; no new data or analysis.	Rejected - not relevant to firefighters
Bateson, T. F. (2014)	Editorial; no new data or analysis.	Rejected - not relevant to firefighters
Bernstein, D., et al. (2013)	This review concentrates on the specific question of risk from chrysotile asbestos and as such is not relevant to firefighters.	Review no new data. Rejected - no relevance to firefighters
Blomberg, A. (2012)	Review without any additional analysis of data and no reference to firefighters.	Review no new data. Rejected - no relevance to firefighters
Boffetta, P., et al. (2010)	This study looked generally at the occupational association of cancer in France but made no reference to firefighters	Rejected - no relevance to firefighters
Bourgkard, E., et al. (2013)	Comparison of methodologies with no novel data and no mention of firefighters	Rejected - no relevance to firefighters
Brenner, D. R., et al. (2010)	A case-control study of 445 cases of lung cancer diagnosed between 1997 and 2002, compared with 425 population controls and 523 hospital controls looked at environmental tobacco smoke exposure and occupation but made no reference to firefighters	Rejected - no relevance to firefighters
Bruske-Hohlfeld, I. (2009)	Review; no new data.	Rejected - no relevance to firefighters
Bunn, W. B. and T. W. Hesterberg (2011)	Letter to the editor; no new data.	Rejected - not relevant to firefighters
Burki, T. (2011)	Editorial; no new data or analysis.	Rejected - not relevant to firefighters
Carel, R., et al. (2007)	Describes a multi-centre case-control study from Eastern Europe of 2,205 lung cancer cases. One ISCO code used is specified as firemen but this does not correspond with the relevant code for firefighters.	Rejected - no relevance to firefighters
Cassidy, A., et al. (2007)	Case-control study of silica exposure and 2,852 cases of lung cancer in 7 European countries. No reference to firefighters.	Rejected - no relevance to firefighters
Cellier, C., et al. (2013)	Review of a very small number of cases of occupational lung cancer considering specific chemical exposures.	Rejected - no relevance to firefighters
Chambaz, A., et al. (2014)	Paper describes an analytical approach to case-control studies but does not contain any novel data.	Rejected - no relevance to firefighters

Choudat, D. (2008)	Review: no new data.	Rejected - no relevance to firefighters
Clement-Duchene, C., et al. (2010)	Study of 1,493 lung cancer cases concentrating on environmental tobacco smoke and known lung carcinogens. No mention of firefighters.	Rejected - no relevance to firefighters
Consonni, D., et al. (2010)	A study of 2,100 Italian lung cancer cases looked at occupational association but firefighters were not mentioned.	Rejected - no relevance to firefighters
Corbin, M., et al. (2012)	Report describes a novel approach to statistical analysis of studies but does not consider occupational exposure and made no reference to fire fighters.	Rejected - no relevance to firefighters
Craighead, J. E. (2011)	Review; no new data.	Rejected - no relevance to firefighters
Dahmann, D., et al. (2008)	Report describes an approach to exposure assessment using silica as an example. There is no analysis to judge occupational exposures and no mention of firefighters.	Rejected - no relevance to firefighters
De Matteis, S., et al. (2012)	A study of 1537 lung cancer cases and occupational exposure using a Job exposure matrix to calculate exposure to a range of specific substances (asbestos, silica, nickel-chromium, PAH). The analysis concluded on the carcinogenicity of the substances investigated but made no reference to firefighters.	Rejected - no relevance to firefighters
Dela Cruz, C. S., et al. (2011)	Review; no new data.	Rejected - no relevance to firefighters
Dresler, C. (2013)	Review; no new data.	Rejected - no relevance to firefighters
Dunning, K. K., et al. (2012)	Study of cohort exposed to vermiculite and asbestos but with no specific relevance to firefighters.	Rejected - no relevance to firefighters
Everatt, R. P., et al. (2007)	A study of 298 lung cancer patients and four with mesothelioma in Lithuania concentrated on asbestos exposure and related cancers. There is no mention of firefighters or related occupation.	Rejected - no relevance to firefighters
Ferrer, J. and M. J. Cruz (2008)	Rejected - foreign language paper with no relevant novel data.	
Field, R. W. and B. L. Withers (2012)	Review; no new data.	Rejected - no relevance to firefighters
Frost, G., et al. (2011)	Report concentrates on the interaction between smoking and asbestos exposure.	Rejected - no relevance to firefighters
Gisquet, E., et al. (2011)	Report is concerned with approaches to reporting of data on mesothelioma rather than any novel presentation of data. There is no specific occupational analysis and firefighters are not mentioned.	Rejected - no relevance to firefighters
Gomez Raposo, C., et al. (2007)	Rejected - foreign language paper with no relevant novel data.	
Guida, F., et al. (2011)	A study of 2,923 French lung cancer cases looked for occupational associations but made no reference to firefighters or any similar occupation even under the categories with less than 10 cases.	Rejected - no relevance to firefighters
Hosseini, M., et al. (2009)	Iranian study of 242 lung cancer cases and association with smoking and exposure to a range of potential carcinogens. No mention of firefighters.	Rejected - no relevance to firefighters
Hutchings, S. and L. Rushton (2011)	Review; no new data.	Rejected - no relevance to firefighters
Jamrozik, E., et al. (2011)	Review; no new data.	Rejected - no relevance to firefighters
Kachuri, L., et al. (2014)	Occupational exposure to crystalline silica and lung cancer case-control study from Canada based on 1681 cases makes no reference to firefighters.	Rejected - no relevance to firefighters

Komus, N., et al. (2008)	Rejected - foreign language paper with no relevant novel data.	
Lacourt, A., et al. (2014)	Case-control study concentrates on mesothelioma (437 cases) and asbestos exposure. Makes no reference to firefighters.	Rejected - no relevance to firefighters
Lan, Q., et al. (2015)	Although the study is investigating a mechanism of carcinogenesis the end-point investigated is not a cancer. There is no mention of or relevance to firefighters.	Rejected - no relevance to firefighters
Lee, H. E. and H. R. Kim (2010)	This Korean report describes a range of common occupational exposures and potential carcinogens but does not make any reference to firefighters.	Rejected - no relevance to firefighters
Lee, S. H., et al. (2015)	Excluded - Non-cancer.	Rejected - no relevance to firefighters
Luce, D. and I. Stucker (2011)	Summary of study characteristics (a group of 2,926 lung cancer cases, a group of 2,415 head and neck cancer cases, and a common control group of 3,555 subjects) but no analysis of occupational association and no mention of firefighters.	Rejected - no relevance to firefighters
Luqman, M., et al. (2014)	Based on 400 lung cancer cases and an analysis of lifestyle and occupation this study attempts to characterise the risk factors for lung cancer in the Pakistani population. There is no mention of firefighters.	Rejected - no relevance to firefighters
Marinaccio, A., et al. (2008)	A review of all lung (536,538) and pleural cancer (12,216) deaths in Italy between 1980 and 2001 analysed to establish the contribution of asbestos to the lung cancer rates. No mention of firefighters.	Rejected - no relevance to firefighters
Mattei, F., et al. (2014)	French study of 2,926 cases of lung cancer and association with solvent exposure. No mention of firefighters.	Rejected - no relevance to firefighters
McHugh, M. K., et al. (2010)	An analysis of 212 cases of lung cancer among Mexican-Americans considered a range of occupations but not firefighters.	Rejected - no relevance to firefighters
Mirabelli, D. (2009)	Editorial; no new data or analysis.	Rejected - not relevant to firefighters
Mosavi-Jarrahi, A., et al. (2009)	Study of Iranian population with the objective of estimating the proportion of cancers which related to occupation. Limited exposure categories defined and no mention of firefighters.	Rejected - no relevance to firefighters
Olsson, A. C., et al. (2011)	Study of 13,304 lung cancer cases and association with diesel exhaust exposure. No mention of firefighters.	Rejected - no relevance to firefighters
Olsson, A. C., et al. (2011)	European study of 2,624 lung cancer cases and association with occupation, characterised by specific exposures to a range of substances including asbestos, metals, arsenic, cadmium, chromium, nickel, PAH and silica. No mention of firefighters.	Rejected - no relevance to firefighters
Pairon, J. C., et al. (2014)	Study investigating the pathology of asbestos-related cancer but with no reference to firefighters.	Rejected - no relevance to firefighters
Park, R. M., et al. (2012)	Study investigated association between respiratory exposure to arsenic and cadmium and lung cancer. No mention of firefighters.	Rejected - no relevance to firefighters
Peters, S., et al. (2012)	A combination of European case-control studies described as the SYNERGY project included 17,705 cases of lung cancer. The project considered exposure to several risk factors (organic dust, endotoxin and contact with animals or fresh animal products) but made no reference to specific occupational categories or to firefighters.	Rejected - no relevance to firefighters
Peters, S., et al. (2011)	This study considered only the methodology of assessing occupational exposure particularly for the analysis of a large combined case-control study of lung cancer. There is no specific consideration of firefighters.	Rejected - no relevance to firefighters
Peters, S., et al. (2012)	A combination of European case-control studies described as the SYNERGY project included 17,705 cases of lung cancer. The project considered exposure to 5 carcinogenic agents (Asbestos, Chromium, Nickel, PAH and respirable quartz), but made no reference to specific occupational categories or to firefighters.	Rejected - no relevance to firefighters
Pintos, J., et al. (2012)	Study of 1,082 lung cancer cases from Montreal and association with diesel exhaust exposure. No mention of firefighters.	Rejected

Ramanakumar, A. V., et al. (2008)	Combined study of two sets of lung cancer cases (857 and 1,236) looking at association with carbon black, titanium dioxide and talc exposure. No mention of firefighters	Rejected - no relevance to firefighters
Recio-Vega, R., et al. (2013)	Study of PCBs and potential impact of genetic polymorphism on consequent cancer rates. No analysis by occupation and no mention of firefighters.	Rejected - no relevance to firefighters
Robinson, C. F., et al. (2011)	Study of occupational cancer in US women makes no mention of firefighters or any related occupation.	Rejected - no relevance to firefighters
Rouge-Bugat, M. E., et al. (2012)	Rejected - Duplicate	
Sancini, A., et al. (2010)	Excluded - Non-cancer.	Rejected - no relevance to firefighters
Scarselli, A., et al. (2008)	No new epidemiological data and no mention of firefighters as an occupation.	Rejected - no relevance to firefighters
Silverstein, M. A., et al. (2009)	Report describes approaches to improve the risk assessment for cancer from asbestos exposure but makes no reference to any occupation and not to firefighters.	Rejected - no relevance to firefighters
Sisti, J. and P. Boffetta (2012)	Review; no new data.	Rejected - no relevance to firefighters
Stayner, L., et al. (2007)	The study concentrates on the consequences of exposure to environmental tobacco smoke.	Rejected - no relevance to firefighters
Steenland, K. and E. Ward (2014)	Review; no new data.	Rejected - no relevance to firefighters
Suda, K., et al. (2011)	A study of the genetic profile of lung cancer types but no reference to occupational exposures or to firefighters.	Rejected - no relevance to firefighters
Tse, L. A., et al. (2011)	Based on analysis of occupational data for 132 lung cancer cases this study concluded that silica dust, diesel exhaust and painting work are the main occupational risk factors for lung cancer in non-smoking Chinese adults. The occupational categories are very broad and none appear to correspond to firefighters.	Rejected - no relevance to firefighters
Tse, L. A., et al. (2009)	This study considered 132 never-smokers from a total of 1,208 lung cancer cases and investigated causative factors particularly environmental tobacco smoke exposure. No mention of firefighters.	Rejected - no relevance to firefighters
Tse, L. A., et al. (2012)	Based upon 1,208 cases of lung cancer in Hong Kong and analysis of occupation this study examines a range of risk factors but makes no reference to firefighters.	Rejected - no relevance to firefighters
van der Bij, S., et al. (2013)	Approaches to asbestos cancer risk assessment which makes reference to exposure levels but not to occupation.	Rejected - no relevance to firefighters
Veglia, F., et al. (2007)	This study followed 200,000 individuals for > 6 years and looked at association of diagnosis of lung cancer with 52 different high-risk job categories. Firefighters were not included as a category and no mention is made of occupational risk to firefighters.	Rejected - no relevance to firefighters
Vehmas, T. (2008)	This study examines the factors affecting pulmonary nodule detection in occupational screening studies in Finland. Makes no reference to firefighters	Excluded - Non-cancer. Rejected - no relevance to firefighters
Verger, P., et al. (2008)	No new data on cancer rates and occupational exposures.	Rejected - no relevance to firefighters
Vida, S., et al. (2010)	Combined study of two sets of lung cancer cases (857 and 738) looking at association with silica exposure. No mention of firefighters	Rejected - no relevance to firefighters
Vizcaya, D., et al. (2013)	Combined study of two sets of lung cancer cases (851 and 1,165) looking at association with chlorinated solvent exposure. No mention of firefighters	Rejected - no relevance to firefighters

Wild, P., et al. (2008)	Review; no new data.	Rejected - no relevance to firefighters
Wild, P., et al. (2012)	Study of 246 lung cancer cases looking at association with several exposures and occupations. No mention of firefighters.	Rejected - no relevance to firefighters
Yenugadhati, N., et al. (2009)	The occupational profiles of 2,988 lung cancer cases from British Columbia recorded between 1983 and 1990 were compared with a control group of patients with cancers at other sites, excluding those that are strongly related to smoking. Data of lifestyle and occupation were obtained by self-administered questionnaire. Although the analysis covers wide range of occupations firefighters are not mentioned.	Rejected - no relevance to firefighters
Yoshizawa, Y. (2008)	Rejected - foreign language paper with no relevant novel data.	
Zaebst, D. D., et al. (2009)	Report relates to shipyard workers and correlation of exposures such as asbestos, welding fumes. No mention of firefighters.	Rejected - no relevance to firefighters
Mesothelioma		
Aguilar-Madrid, G., et al. (2010)	The study is based on 119 cases of pleural mesothelioma in Mexican residents compared with 353 controls. Analysis of occupation was related to asbestos exposure but no mention was made of firefighters.	Rejected - no relevance to firefighters
Ahn, Y. S. and S. K. Kang (2009)	Study considers asbestos-related cancers which have been compensated in Korea. No mention is made of firefighters as a risk category.	Rejected - no relevance to firefighters
Binazzi, A., et al. (2013)	Rejected - foreign language paper with no relevant novel data.	
Brown, T., et al. (2012)	Duplicate item, also retrieved under larynx	Rejected - Duplicate
Camiade, E., et al. (2013)	Case-control study from France analysing potential occupational and non-occupational exposures of 385 cases of pleural mesothelioma in women. No reference was made to firefighters.	Rejected - no relevance to firefighters
Chamming's, S., et al. (2013)	Report deals with compensation for mesothelioma as an occupational disease in France. There is no mention of firefighters.	Rejected - no relevance to firefighters
Chu, H., et al. (2009)	Describes methodology of risk estimation for asbestos-related mesothelioma based upon the quality of exposure data. No mention of firefighters.	Rejected - no relevance to firefighters
Everatt, R. P., et al. (2007)	Study of occupational asbestos exposure related to respiratory cancer including mesothelioma. No mention of firefighters or a relevant occupational category	Rejected - no relevance to firefighters
Fazzo, L., et al. (2012)	Study of mesothelioma and regional variation in Italy. No occupational associations mentioned and firefighters not mentioned.	Rejected - no relevance to firefighters
Kishimoto, T., et al. (2010)	Study of the occupational associations with mesothelioma in Japan based upon 442 cases. No mention of firefighters.	Rejected - no relevance to firefighters
Klaunig, J. E. (2008)	Describes the process and mechanism of acrylamide toxicity and carcinogenicity but with no mention of occupational exposures or firefighters.	Rejected - no relevance to firefighters
Lacourt, A., et al. (2014)	Study of effects of exposure to asbestos and ceramic fibres and associated risk of pleural mesothelioma. No mention of firefighters.	Rejected - no relevance to firefighters
Lacourt, A., et al. (2014)	A total of 988 cases and 1,125 controls ever-exposed to asbestos were examined for association with occupational exposure. Considers asbestos and ceramic fibre exposure but no mention of firefighters.	Rejected - no relevance to firefighters
Lacourt, A., et al. (2010)	Used the job exposure matrix approach to establish occupational exposure for pleural mesothelioma cases (463 +371) in France.	Rejected - no relevance to firefighters
Le Neindre, B., et al. (2007)	Study of the compensation for pleural mesothelioma among 141 cases from Normandy, France. No mention of firefighters or similar occupations.	Rejected - no relevance to firefighters
Lee, H. E. and H. R. Kim (2010)	Study of occupational cancer in Kores but focus is on specific established causative agents not the actual occupation. No mention of firefighters.	Rejected - no relevance to firefighters

Lin, R. T., et al. (2007)	Study of generic association between asbestos use/consumption in countries and the rates of mesothelioma. Firefighters are not mentioned.	Rejected - no relevance to firefighters
Marinaccio, A., et al. (2007)	Rejected - foreign language paper with no relevant novel data.	
Marinaccio, A., et al. (2010)	Analysis of extra-pleural mesothelioma in Italy in relation to occupation and asbestos exposure but no mention of firefighters.	Rejected - no relevance to firefighters
Marinaccio, A., et al. (2012)	Study describes regional variations in pleural mesothelioma with some associations with occupation but no mention of firefighters.	Rejected - no relevance to firefighters
Marinaccio, A., et al. (2008)	Describes an approach to analysis of asbestos related mortality in Italy. No occupational associations identified and no mention of firefighters.	Rejected - no relevance to firefighters
Marinaccio, A., et al. (2012)	Report describes the compensation for mesothelioma in Italy with assessment of the risk of not seeking compensation. No mention of firefighters.	Rejected - no relevance to firefighters
Marrett, L. D., et al. (2008)	Editorial; no new data or analysis	Editorial no new data or analysis. Rejected - not relevant to firefighters
McNamee, R., et al. (2008)	Summary of trends in incidence rates for occupational diseases including mesothelioma but with no mention of specific occupations and no mention of firefighters.	Rejected - no relevance to firefighters
Mendez-Vargas, M. M., et al. (2010)	Study of 3,700 cases of mesotheliomas from Mexico and association with occupation. No relevance to firefighters.	Rejected - no relevance to firefighters
Mensi, C., et al. (2011)	An analysis of cases of pleural mesothelioma in Lombardy, Italy for association with occupation but with no mention of firefighters.	Rejected - no relevance to firefighters
Mensi, C., et al. (2012)	Investigation of the occupational associations with testicular mesothelioma and link with asbestos is demonstrated but there is no mention of firefighters.	Rejected - no relevance to firefighters
Metintas, M., et al. (2008)	Study of mesothelioma and asbestos exposure in a non-occupational context.	Rejected - no relevance to firefighters
Mise, K., et al. (2009)	Study of 137 cases of pleural mesothelioma in Croatia. Some occupational associations mentioned with one case reported to be a fireman, but no indication of whether this was a firefighter or other boiler-related occupation.	Rejected - no relevance to firefighters
Montomoli, L., et al. (2007)	Rejected - foreign language paper with no relevant novel data.	
Neumann, V., et al. (2013)	Review; no new data.	Rejected - no relevance to firefighters
O'Connor, M., et al. (2009)	Editorial; no new data or analysis.	Rejected - not relevant to firefighters
Ohar, J. A., et al. (2007)	Report describes the characterisation of a phenotype of mesothelioma but with no reference to occupational association and no reference to firefighters.	Rejected - no relevance to firefighters
Olsen, N. J., et al. (2011)	Report considered the relationship between mesothelioma and home-renovation exposure to asbestos but otherwise no mention of occupation or firefighters.	Rejected - no relevance to firefighters
Oxtoby, K. (2009)	Editorial; no new data or analysis.	Rejected - not relevant to firefighters
Pairon, J. C., et al. (2008)	Review, mainly in French, of the relationship between occupation and incidence of lung cancer and mesothelioma. There are no new data and no mention of firefighters.	Review no new data. Rejected - no relevance to firefighters

Pairon, J. C., et al. (2013)	This paper explores the relationship between pleural plaques and mesothelioma but gives no specific occupational associations and does not mention firefighters.	Rejected - no relevance to firefighters
Payne, J. I. and E. Pichora (2009)	Reviews filing of compensation claims for mesothelioma in Ontario. Makes no mention of firefighters.	Rejected - no relevance to firefighters
Plato, N. P., et al. (2013)	Brief note of conference proceedings looking at relationship between exposure and latency for mesothelioma but with no information on specific occupations including firefighters.	Rejected - no relevance to firefighters
Rake, C., et al. (2009)	Study of occupational association of 622 mesothelioma cases in the UK, with no mention of firefighters.	Rejected - no relevance to firefighters
Roggli, V. L. and R. T. Vollmer (2008)	Review no new data. Rejected - no relevance to firefighters	
Rolland, P., et al. (2010)	Based on analysis of occupation for 462 case of mesothelioma in a French multicentre study there is no mention of firefighters.	Rejected - no relevance to firefighters
Rosell-Murphy, M. I., et al. (2013)	Describes methodology but gives no details of results and makes no mention of firefighters.	Rejected - no relevance to firefighters
Rushton, L., et al. (2010)	The wide -ranging analysis reported for UK cancer deaths in 2005 identified risks for various occupations but firefighters were not mentioned.	Rejected - no relevance to firefighters
Saric, M., et al. (2008)	Report describes a possible connection between mesothelioma and polio vaccination but describes no other associations and makes no mention of firefighters.	Rejected - no relevance to firefighters
Tarry, S. L., Jr. (2007)	Letter to the editor; no new data.	Rejected - not relevant to firefighters
Toyokuni, S. (2009)	Provides a description of the mechanism of carcinogenesis of asbestos but no data on epidemiology.	Review no new data. Rejected - no relevance to firefighters
van der Bij, S., et al. (2013)	Report describes exposure -response relationship for asbestos low-dose exposures, but makes no mention of firefighters.	Rejected - no relevance to firefighters
Yarborough, C. M. (2007)	Review; no new data.	Rejected - no relevance to firefighters
Zhang, J., et al. (2013)	Describes a method of statistical analysis, but has no new data and does not make any reference to occupations.	Rejected - no relevance to firefighters
Multiple Myeloma		
Boffetta, P., et al. (2008)	Data from 2,028 cases of lymphoma from 7 European countries were the basis of this study of the effects of UV light on the risk of lymphoma and multiple myeloma. There was no mention of firefighters.	Rejected - no relevance to firefighters
Brown, T. and L. Rushton (2012)	The study of cancers recorded in UK during 2004 and their association with exposure to a variety of established carcinogens did not consider specific occupational exposure or any measure of individual employment and makes no mention of firefighters.	Rejected - no relevance to firefighters
Cogliano, V. J., et al. (2011)	This report seeks to extend the IARC opinion on carcinogenicity of benzene and is review and comment rather than a report of novel data.	Review no new data. Rejected - no relevance to firefighters
Costantini, A. S., et al. (2008)	Based on 586 cases of leukaemia from a multicentre study in Italy the exposure to solvents was estimated and the data analysed for evidence of any association with that exposure. Firefighters are not mentioned in the analysis.	Rejected - no relevance to firefighters
Galbraith, D., et al. (2010)	Review; no new data	Rejected - no relevance to firefighters

Ghosh, S., et al. (2011)	Based on 342 Canadian cases of multiple myeloma the study analyses the association with a range of occupations, however there is no mention of firefighters.	Rejected - no relevance to firefighters
Gold, L. S., et al. (2010)	An analysis of 180 cases of multiple myeloma form the Seattle and Detroit area made no mention of firefighters.	Rejected - no relevance to firefighters
Gold, L. S., et al. (2011)	An analysis of solvent use by 180 cases of multiple myeloma form the Seattle and Detroit area made no mention of firefighters.	Rejected - no relevance to firefighters
Graber, J. M., et al. (2012)	Letter to the editor about study by Ghosh et al. No new data and no mention of firefighters.	Letter to the editor - no new data. Rejected - not relevant to firefighters
Infante, P. F. (2011)	A call for a further IARC review on the carcinogenicity of benzene but no evidence of new data and no mention of firefighters.	Editorial no new data or analysis. Rejected - not relevant to firefighters
Omoti, C. E., et al. (2012)	A study of 252 cases of leukaemia among hospital patients in Benin, Nigeria looking for association with occupation but with no mention of firefighters.	Rejected - no relevance to firefighters
Orsi, L., et al. (2007)	French study of 824 cases of NHL, Hodgkin's lymphoma, multiple myeloma and other lymphoproliferative disorders. The analysis considers a range of occupations but makes no mention of firefighters.	Rejected - no relevance to firefighters
Perrotta, C., et al. (2013)	Based upon a pooled analysis of five case control studies with a total of 1,959 multiple myeloma cases a wide range of occupational associations is considered but firefighters do not feature and are not mentioned in that analysis.	Rejected - no relevance to firefighters
NHL		
Apostoli, P., et al. (2011)	Rejected - foreign language paper with no relevant novel data.	
Aschebrook-Kilfoy, B., et al. (2014)	A pooled analysis of 14 case-control studies from USA, Australia and Europe compared a total of 324 cases of non-Hodgkin lymphoma (NHL) with 17,217 controls. The analysis considered effects of medical history and occupation. In the occupational analysis firefighter was not a listed occupation and no association was identified with NHL.	Rejected - no relevance to firefighters
Balasubramaniam, G., et al. (2013)	From Mumbai in India 3990 cases of lymphoma were compared with 1,383 controls who were hospital patients free from cancer. Lifestyle and occupation details were obtained by interview. Firefighters were not identified in the study in any way.	Rejected - no relevance to firefighters
Barry, K. H., et al. (2011)	Study is investigating genetic polymorphism of metabolic capacity of organic solvents as a factor in the association of such exposure with NHL.	Rejected - no relevance to firefighters
Bracci, P. M., et al. (2014)	An analysis of pooled data from 14 case-control studies from USA, Australia and Europe compared 1,052 cases of marginal zone lymphoma with 13,766 controls. Association with occupation was found for carpenters but firefighters did not feature in the occupations identified among the cases.	Rejected - no relevance to firefighters
Brown, T. and L. Rushton (2012)	A review of causative factors for all haematopoietic cancers including leukaemia and NHL. No mention of firefighters among the occupations where such exposures could occur.	Review no new data. Rejected - no relevance to firefighters
Cerhan, J. R., et al. (2014)	A pooled analysis of 4,667 cases from 19 studies of B-cell lymphoma compared with 22,639 controls considered various occupations and risk factors but did not mention firefighters as an occupation.	Rejected - no relevance to firefighters
Chia, S. E., et al. (2012)	A case-control study in Singapore was based on 465 cases of NHL diagnosed between 2004 and 2008 compared with 830 controls recruited from non-cancer patients of the same hospitals. Firefighters were not identified as an occupational group in this study.	Rejected - no relevance to firefighters

Chiu, B. C. and N. Hou (2015)	Abstract does not indicate that this paper is likely to identify risks of NHL for any occupational group and no indication that firefighters are considered. Appears to be more concerned with the mechanism of origination of this cancer type.	Rejected - no relevance to firefighters
Chiu, B. C. and N. Hou (2015)	Rejected – Duplicate.	
Cocco, P., et al. (2013)	A pooled analysis of 4 international case-control studies of NHL with a total of 3,788 NHL cases and 4,279 controls. There is no mention of firefighters as an occupation in the analysis of associations with TCE exposures.	Rejected - no relevance to firefighters
Galbraith, D., et al. (2010)	Review; no new data.	Rejected - no relevance to firefighters
Hartge, P. and M. T. Smith (2007)	Review; no new data.	Rejected - no relevance to firefighters
Hoffmann, W., et al. (2008)	A study from Germany of 1,430 cases of lymphoma and leukaemia recorded between 1996 and 1998 compared with 3,041 randomly selected controls investigated various factors for association including pesticides, EMF, nuclear power stations and occupational exposure but made no reference to firefighters or relevant exposures.	Rejected - no relevance to firefighters
Hosnijeh, F. S., et al. (2012)	Review; no new data.	Rejected - no relevance to firefighters
Jiao, J., et al. (2012)	Study of genetic variation of DNA repair genes and association of NHL with solvent exposure. No mention of firefighters.	Rejected - no relevance to firefighters
Kane, E. V. and R. Newton (2010)	Review; no new data.	Rejected - no relevance to firefighters
Kane, E. V. and R. Newton (2010)	Review; no new data.	Rejected - no relevance to firefighters
Karunanayake, C. P., et al. (2008)	The occupations of 513 cases of NHL from six Canadian provinces were compared with those of 1,506 population controls. Of a range of occupational exposures only diesel exhaust fumes or ionizing radiation showed an association with NHL. Occupations showing association were farmer and machinist firefighters were not mentioned.	Rejected - no relevance to firefighters
Linet, M. S., et al. (2014)	A pooled analysis of 3530 cases from 19 studies of follicular lymphoma compared with 22,639 controls considered various occupations and risk factors but did not mention firefighters as an occupation.	Rejected - no relevance to firefighters
Mbulaiteye, S. M., et al. (2014)	A pooled analysis of 295 cases from 18 studies of sporadic Burkitt lymphoma/leukaemia compared with 21,818 controls considered various occupations and risk factors but did not mention firefighters as an occupation.	Rejected - no relevance to firefighters
McBride, D. I., et al. (2009)	Mortality study of workers exposed to trichlorophenol. No mention of firefighters.	Rejected - no relevance to firefighters
Purdue, M. P., et al. (2011)	Case-control study looking at TCE exposure and NHL with no reference to occupations or firefighters.	Rejected - no relevance to firefighters
Richardson, D. B., et al. (2008)	Occupation and exposures of 858 cases of NHL and chronic lymphocytic leukaemia recorded between 1986 and 1998 were compared with those of 1,821 population controls. Associations were found for agricultural workers/farmers, blacksmiths, toolmakers and machine-tool operators but firefighters were not mentioned.	Rejected - no relevance to firefighters
Schenk, M., et al. (2009)	A comparison of the occupation of 1,189 cases of NHL in 4 geographic areas of the USA with 982 population controls identified various occupations associated with an elevated risk of NHL risk but did not mention firefighters.	Rejected - no relevance to firefighters

Skibola, C. F., et al. (2014)	A pooled analysis of 152 cases from 16 case-control studies of acute lymphocytic leukaemia compared with 23,096 controls considered various occupations and risk factors but did not mention firefighters as an occupation.	Rejected - no relevance to firefighters
Skibola, C. F., et al. (2014)	Rejected – Duplicate.	
Slager, S. L., et al. (2014)	pooled analysis of 2440 cases from 13 case-control studies of chronic lymphocytic leukaemia and small lymphocytic leukaemia compared with 15,186 controls considered various occupations and risk factors but did not mention firefighters as an occupation.	Rejected - no relevance to firefighters
Slager, S. L., et al. (2014)	Rejected - Duplicate	
Smedby, K. E., et al. (2014)	A pooled analysis of 557 cases from 13 case-control studies of mantle cell lymphoma compared with 13,776 controls considered various occupations and risk factors but did not mention firefighters as an occupation.	Rejected - no relevance to firefighters
Smedby, K. E., et al. (2014)	Rejected - Duplicate	
Soni, L. K., et al. (2007)	Study of 387 cases of NHL examining the relationship with sun exposure. No specific occupational categories considered an dno mention of firefighters.	Rejected - no relevance to firefighters
Swaen, G. M., et al. (2010)	Letter to the editor - no new data.	Rejected - not relevant to firefighters
Tranah, G. J., et al. (2009)	Case-control study of NHL (1,591 cases) from USA examining the relationship with solvent exposure. No mention of firefighters.	Rejected - no relevance to firefighters
Vajdic, C. M., et al. (2014)	A pooled analysis of 374 cases from 11 case-control studies of lymphoplasmocytic lymphoma/Waldenström's macroglobulinemia compared with 23,096 controls considered various occupations and risk factors but did not mention firefighters as an occupation.	Rejected - no relevance to firefighters
Vajdic, C. M., et al. (2014)	Rejected - Duplicate	
Wang, R., et al. (2009)	Case-control study of 601 cases of NHL in women and association with solvent exposure. No mention of firefighters.	Rejected - no relevance to firefighters
Wang, S. S., et al. (2014)	A pooled analysis of 584 cases from 15 case-control studies of peripheral T-cell lymphomas compared with 15,912 controls considered various occupations and risk factors but did not mention firefighters as an occupation.	Rejected - no relevance to firefighters
Wang, S. S., et al. (2014)	Rejected - Duplicate	
Weed, D. L. (2010)	Review and meta-analysis in relation to benzene exposure. No new data.	Rejected - no relevance to firefighters
Wong, O., et al. (2010)	649 cases of NHL identified in Shanghai between 2003 and 2008 were compared for occupation and lifestyle with 1,298 controls selected form hospital patients without lymphatic or haematopoietic cancers. The occupational analysis was limited and did not mention firefighters.	Rejected - no relevance to firefighters
Oesophagus		
Bevan, R., et al. (2012)	Review; no new data.	Rejected - no relevance to firefighters
Huang, S. H., et al. (2012)	A comparison of occupation of 326 cases of squamous cell carcinoma of the oesophagus with that of 386 age-matched controls made no reference to firefighters.	Rejected - no relevance to firefighters

Li, B., et al. (2015)	Studied the relationship between oesophageal cancer and asbestos exposure. No mention of firefighters.	Rejected - no relevance to firefighters
Mohammad Ganji, S., et al. (2010)	Study of the mechanism of oesophageal carcinogenesis. No consideration of occupation or mention of firefighters.	Rejected - no relevance to firefighters
Popescu, C. R., et al. (2010)	Review no new data.	Rejected - no relevance to firefighters
Richiardi, L., et al. (2012)	A study of 1,851 patients with cancer of oral cavity, oropharynx, larynx or oesophagus compared their occupation with that of 1,851 controls identified increased cancer risk for a number of occupations but did not mention firefighters.	Rejected - no relevance to firefighters
Roshandel, G., et al. (2012)	Review; no new data.	Rejected - no relevance to firefighters
Santibanez, M., et al. (2008)	Occupation and exposures of 185 cases of oesophageal cancer from Spain were compared with those of 285 matched controls. Firefighters were not mentioned in the analysis.	Rejected - no relevance to firefighters
Pancreas		
Andreotti, G. and D. T. Silverman (2012)	Review; no new data.	Rejected - no relevance to firefighters
Bosch de Basea, M., et al. (2011)	Reports the relationship between broad occupational categories and exposure to organochlorine compounds in relation to 135 cases of pancreatic cancer. the occupational categories are too broad to derive any relevance for firefighters.	Rejected - no relevance to firefighters
Fritschi, L., et al. (2015)	Australian case-control study of pancreatic cancer (504 cases) and nitrosamine exposure. No evidence of any positive association and no mention of firefighters.	Rejected - no relevance to firefighters
Hart, A. R., et al. (2008)	Review; no new data.	Rejected - no relevance to firefighters
Lo, A. C., et al. (2007)	Review of the occupation and lifestyle of 194 pancreatic cancer cases from Egypt and an equal number of matched controls did not mention firefighters or any risk factors which might relate to that occupation.	Rejected - no relevance to firefighters
Ojajarvi, A., et al. (2007)	Review of 261 studies published between 1969 and 1998 relating to pancreatic cancer and job titles. Firefighters were not mentioned in this review.	Review no new data. Rejected - no relevance to firefighters
Santibanez, M., et al. (2010)	A study of 161 cases of oesophageal cancer from Spain compared with 455 matched controls did not mention firefighters.	Rejected - no relevance to firefighters
Prostate		
Bradley, C. J., et al. (2007)	Study is of employment consequences of surviving breast and prostate cancer and does not relate cancer to occupation.	Rejected - no relevance to firefighters
Christensen, K. Y., et al. (2013)	Study of occupational exposure to chlorinated solvents and prostate cancer. Firefighters do not feature in the analysis.	Rejected - no relevance to firefighters
Costa, G., et al. (2010)	Study of shift work in relation to cancer but makes no mention of firefighters as a potentially affected occupation.	Rejected - no relevance to firefighters
Dombi, G. W., et al. (2010)	Describes the use of neural network analysis to identify occupational associations with cancer risk. There is no conclusion about specific occupations and no mention of firefighters.	Rejected - no relevance to firefighters
Doolan, G., et al. (2014)	Review; no new data.	Rejected - no relevance to firefighters
Doolan, G. W., et al. (2014)	Investigation of 1,436 cases of prostate cancer and the relationship with physical activity at work. No details of specific occupations and no mention of firefighters.	Rejected - no relevance to firefighters

Erren, T. C., et al. (2011)	Letter to the editor - no new data.	Rejected - not relevant to firefighters
Erren, T. C., et al. (2015)	Letter to the editor - no new data.	Rejected - not relevant to firefighters
Ferris, I. T. J., et al. (2011)	Rejected - foreign language paper with no relevant novel data.	
Freeman, K. S. (2010)	Editorial; no new data or analysis.	Rejected - not relevant to firefighters
Fritschi, L., et al. (2007)	Examination of 606 cases of prostate cancer in relation to various occupational exposures (pesticides, fertilisers, metals, wood dust, oils, diesel exhaust and polyaromatic hydrocarbons) but with no positive associations and no mention of firefighters.	Rejected - no relevance to firefighters
Hammer, G. I. P., et al. (2015)	Studied prostate cancer in relation to shift work in a cohort of German production workers. There is no mention of firefighters.	Rejected - no relevance to firefighters
Krishnadasan, A., et al. (2008)	Study of the relationship between physical activity and prostate cancer with no specific occupations identified and no mention of firefighters.	Rejected - no relevance to firefighters
Lagiou, A., et al. (2008)	Studies the relationship between physical activity and prostate cancer and prostate hyperplasia. No mention of specific occupations or firefighters.	Rejected - no relevance to firefighters
Neilson, H. K., et al. (2007)	Study of the reliability of personally reported exposure data but with no specific occupational data and no mention of firefighters.	Rejected - no relevance to firefighters
Papantoniou, K., et al. (2015)	Letter to the editor - no new data.	Rejected - not relevant to firefighters
Sass-Kortsak, A. M., et al. (2007)	Case-control study of 760 cases of prostate cancer in Canada, analysed by occupation. Made no mention of firefighters.	Rejected - no relevance to firefighters
Strom, S. S., et al. (2008)	Review of occupational association with 176 cases of prostate cancer in Mexican Americans. No mention of firefighters.	Rejected - no relevance to firefighters
Wang, X. S., et al. (2011)	Review; no new data.	Rejected - no relevance to firefighters
Skin		
Burkhart, C. G. and C. N. Burkhart (2009)	Letter to the editor - no new data.	Rejected - not relevant to firefighters
Caccialanza, M., et al. (2012)	Brief note about basal cell carcinoma and sunlight exposure. No mention of relevance to firefighters.	Letter to the editor. Rejected - not relevant to firefighters
Diepgen, T. L., et al. (2012)	Rejected - foreign language paper with no relevant novel data.	
Diepgen, T. L., et al. (2012)	Review; no new data.	Rejected - no relevance to firefighters
Dika, E., et al. (2010)	Review; no new data.	Rejected - no relevance to firefighters
Elsner, P., et al. (2013)	Paper describes procedures to prevent the occurrence of squamous cell carcinoma as an occupational disease but makes no mention of firefighters.	Rejected - no relevance to firefighters
Fartasch, M., et al. (2012)	Review no new data.	Rejected - no relevance to firefighters

Fartasch, M., et al. (2012)	Rejected - foreign language paper with no relevant novel data.	
Fortes, C. and E. de Vries (2008)	A meta-analysis of melanoma and non-UV causes. There is no mention of firefighters.	Rejected - no relevance to firefighters
Hammond, V., et al. (2008)	Study describes the role of protection of workers from UV exposure in reducing occupational skin cancer. No mention of firefighters.	Rejected - no relevance to firefighters
Klaunig, J. E. (2008)	Not relevant	Rejected - Duplicate
Kutting, B. and H. Drexler (2010)	Review with no new data targeted primarily at investigating methods of prevention. No mention of firefighters.	Rejected - no relevance to firefighters
Lahmann, P. H., et al. (2011)	A prospective study with 16-year follow-up looking at association between physical activity and squamous cell carcinoma. No association was found and firefighters were not mentioned.	Rejected - no relevance to firefighters
LeBlanc, W. G., et al. (2008)	Study examines the frequency of skin examination for cancer in various occupational categories. Although firefighters are mentioned there is no conclusion about cancer and occupation.	Rejected - no relevance to firefighters
Lee, C., et al. (2014)	Study of the impact of sun-screen on non-cancer effects of sun exposure. No mention of firefighters.	Rejected - no relevance to firefighters
Lee, T. K., et al. (2009)	Case-control study of 595 melanoma patients assessing relationship of melanoma with occupational physical activity. No mention of firefighters.	Rejected - no relevance to firefighters
Marehbian, J., et al. (2007)		Rejected - no relevance to firefighters
Melkonian, S., et al. (2011)	A prospective study from Bangladesh on the relationship between arsenic exposure and skin cancer in males. No mention of firefighters or relevant exposures.	Rejected - no relevance to firefighters
Milon, A., et al. (2014)	Study of occupational exposure to UV light and relationship to skin cancer rates. No specific occupation is considered.	Rejected - no relevance to firefighters
Nies, E. and G. Korinth (2008)	This is a brief response to another article about absorption of benzene from gasoline and is not in any way related to firefighters.	Excluded - Non-cancer
Peters, C. E., et al. (2012)	This paper describes the occupational exposure of Canadian workers to UV light and the consequent risk of skin cancer. Firefighters are not listed as an occupation relevant to this study.	Rejected - no relevance to firefighters
Reeder, A. I. (2011)	Letter to the editor - no new data.	Rejected - not relevant to firefighters
Rueff, F. and B. Przybilla (2007)	Rejected - foreign language paper with no relevant novel data.	
Sartorelli, P. (2013)	Rejected - foreign language paper with no relevant novel data.	
Schmitt, J., et al. (2011)	Rejected - foreign language paper with no relevant novel data.	
Schmitt, J. and T. L. Diepgen (2014)	Paper describes the occupations in Germany potentially at risk from skin cancer due to occupational exposure to UV light. Firefighters are not mentioned.	Rejected - no relevance to firefighters
Schmitt, J., et al. (2011)	Rejected - Duplicate	
Sneyd, M. J., et al. (2014)	A population-based case–control study (368 cases and 270 controls) considered the skin condition of the cases and controls but did not investigate occupation exposure.	Rejected - no relevance to firefighters
Suarez, B., et al. (2007)	In a case-control study of 1,585 cases of skin cancer considered occupational causes apart from solar UV. Firefighters did not feature in any part of the analysis.	Rejected - no relevance to firefighters
Surdu, S. (2014)	Review; no new data.	Rejected - no relevance to firefighters

Surdu, S., et al. (2013)	Case-control study of 618 cases of non-melanoma skin cancer considering the role of occupational exposure to UV radiation. No mention of firefighters.	Rejected - no relevance to firefighters
Surdu, S., et al. (2013)	Study of 618 cases of non-melanoma skin cancer and relationship both with UV exposure and arsenic. No mention of firefighters.	Rejected - no relevance to firefighters
Tenkate, T. and M. Kimlin (2008)	Letter to the editor - no new data.	Rejected - not relevant to firefighters
Tobia, L., et al. (2007)	Rejected - foreign language paper with no relevant novel data.	
Young, C. and L. Rushton (2012)	Review of risk factors including occupation for non-melanoma skin cancer. Firefighters are not mentioned as a risk group.	Rejected - no relevance to firefighters
Stomach		
Bevan, R., et al. (2012)	Rejected - Duplicate	
Peng, W. J., et al. (2015)	A meta-analysis and review of the relation between asbestos exposure and stomach cancer. No mention of firefighters.	Rejected - no relevance to firefighters
Santibanez, M., et al. (2012)	Spanish case-control study of 399 cases of stomach cancer investigating occupational association with different histological subtypes of cancer. No mention of firefighters.	Rejected - no relevance to firefighters
Williams, G. M. and M. J. Iatropoulos (2009)	This paper describes animal experimental data on the carcinogenesis of ethyl acrylate in rats. There is no relevance to occupational exposures or firefighters.	Rejected - no relevance to firefighters
Testes		
Klaunig, J. E. (2008)	Not relevant	Rejected - Duplicate
Lindbohm, M. L., et al. (2011)	Paper considers the consequences for subsequent employment of diagnosis of cancer. No mention of firefighters.	Rejected - no relevance to firefighters
McDuffie, H. H., et al. (2007)	Case-control study from Saskatchewan of 517 cases of testicular cancer and consideration of farmers versus non-farmers as the only occupational analysis. No mention of firefighters.	Rejected - no relevance to firefighters
McGlynn, K. A. and B. Trabert (2012)	Review; no new data.	Rejected - no relevance to firefighters
Mensi, C., et al. (2012)	Consideration of occupational factors in the origin of 13 cases of testicular mesothelioma. Asbestos exposure is considered to play an important role but no mention of firefighters.	Rejected - no relevance to firefighters
Mester, B., et al. (2010)	Review; no new data.	Rejected - no relevance to firefighters
Mester, B., et al. (2011)	Describes development of an exposure modelling technique. No relevance to firefighters.	Rejected - no relevance to firefighters
Walschaerts, M., et al. (2007)	Based on 229 French cases of testicular cancer and investigation of family history, occupational and lifestyle factors. No mention of firefighters	Rejected - no relevance to firefighters
Yousif, L., et al. (2013)	A registry-based case-control study of 348 cases of testicular cancer and occupation. Mentioned firefighters in the introduction as a risk group but no later mention in the analysis.	Rejected - no relevance to firefighters
Thyroid		
Brown, T., et al. (2012)	Duplicate.	Rejected - Duplicate
Craig, W. L., et al. (2014)	Paper describes different treatments and surgical procedures applied to thyroid cancer. No mention of firefighters.	Rejected - no relevance to firefighters
Klaunig, J. E. (2008)	Not relevant.	Rejected - no relevance to firefighters
Leux, C. and P. Guenel (2010)	Review; no new data.	Rejected - no relevance to firefighters

Lope, V., et al. (2009)	Consideration of occupation and occupational exposure in the origin of thyroid cancer in the Swedish population. Firefighters do not feature in this analysis.	Rejected - no relevance to firefighters
Peragallo, M. S., et al. (2011)	Rejected - foreign language paper with no relevant novel data.	
Roerink, S. H., et al. (2013)	This study is examining the levels of distress in thyroid cancer patients and makes no analysis of occupation or aetiology of the cancer.	Rejected - no relevance to firefighters
Firefighters		
Beranger, R., et al. (2013)	Review; no new data.	Rejected - no relevance to firefighters
Bianchi, C., et al. (2007)	Rejected - foreign language paper with no relevant novel data.	
Christ, S. L., et al. (2012)	Makes mention of firefighters in the introduction but draws no conclusions relevant to cancer risk in firefighters.	Rejected - no relevance to firefighters
Crawford, J. O. and R. A. Graveling (2012)	Only deals with non-cancer end-points and does not find any consistent association between these and the occupation of firefighter.	Excluded - Non-cancer
Demers, P., et al. (2011)	Conference proceeding abstract data reported more fully by Pukkala et al.	Rejected- Conference note no details
Demers, P. A., et al. (2011)	Conference proceeding abstract data reported more fully by Pukkala et al.	Rejected - Conference note no details
Edelman, D. A., et al. (2008)	No relevance to firefighters. Study of risks of smoking while using oxygen therapy at home.	Rejected - no relevance to firefighters
Fritschi, L. and D. C. Glass (2014)	Rejected - Comment no data.	
Josyula, A. B., et al. (2007)	Excluded - Non-cancer.	
Kahn, S. A., et al. (2015)	Excluded - Non-cancer.	
Kaiser, J. (2012)	Comment; no data.	Rejected - Comment no data
Kitchen, R. H., et al. (2008)	Comment; no data.	Rejected - Comment no data
Kmietowicz, Z. (2015)	Comment; no data.	Rejected - Comment no data
Lucchini, R. G., et al. (2012)	Excluded - Non-cancer.	
Sergentanis, T. N., et al. (2015)	Rejected – Duplicate.	
Wakeford, R. and D. McElvenny (2007)	Editorial; no new data or analysis.	Rejected - not relevant to firefighters
Walsh, J. M., et al. (2014)	Paper describes a screening programme for colorectal cancer in firefighters but does not assess occupational risk for firefighters.	Rejected - no relevance to firefighters
Webber, M. P., et al. (2016)	Rejected – Duplicate.	
Yip, J., et al. (2015)	Rejected – Duplicate.	
Yip, J., et al. (2016)	Rejected – Duplicate.	