Safety and Health at Work 11 (2020) 509–516

Contents lists available at ScienceDirect

Safety and Health at Work

journal homepage: www.e-shaw.net

Original Article

Work Conditions and Practices in Norwegian Fire Departments From 1950 Until Today: A Survey on Factors Potentially Influencing Carcinogen Exposure

Jarle Jakobsen [1,2,*], Ronnie Babigumira [1], Marie Danielsen [1,3], Tom K. Grimsrud [1], Raymond Olsen [4], Cecilie Rosting [4], Marit B. Veierød [2], Kristina Kjærheim [1]

[1] Department of Research, Cancer Registry of Norway, Oslo, Norway
[2] Oslo Centre for Biostatistics and Epidemiology, Department of Biostatistics, Institute of Basic Medical Sciences, University of Oslo, Norway
[3] Department of Research and Collections, Natural History Museum, University of Oslo, Norway
[4] National Institute of Occupational Health in Norway, Oslo, Norway

ARTICLE INFO

Article history:
Received 10 March 2020
Received in revised form
2 June 2020
Accepted 9 July 2020
Available online 18 July 2020

Keywords:
Cancer
Firefighters
Occupational exposure

ABSTRACT

Background: Meta-analyses have shown firefighters to be at an increased risk of several cancer types. Occupational carcinogen exposure may explain these increased risks. This study aims to describe Norwegian fire departments' work conditions from 1950 until today, focusing on factors relevant for potential occupational carcinogen exposure.

Methods: With the help of a reference group, we developed a questionnaire on topics related to occupational exposure to carcinogens for the period 1950–2018. Selected Norwegian fire departments provided department-specific responses.

Results: Sixteen departments, providing fire services for 48% of the Norwegian population as of 2019 and mainly consisting of professional firefighters, responded to our questionnaire. The introduction of synthetic firefighting foams, more regular live fire training, the introduction of chemical diving, and a higher number of diesel-driven fire service vehicles were identified as changes thought to increase exposure to occupational carcinogens. Changes thought to decrease exposure included the switch from negative to positive pressure self-contained breathing apparatuses, the use of self-contained breathing apparatuses during all phases of firefighting, the use of ventilating fans during firefighting, increased attention to flammable materials used during live fire training, increased attention to handling and cleaning of turnout gear and other equipment, and installment of exhaust removal systems in apparatus bays.

Conclusion: Norwegian fire departments' work conditions have seen several changes since 1950, and this could influence firefighters' occupational carcinogen exposure. A peak of carcinogen exposure may have occurred in the 1970s and 1980s before recent changes have reduced exposure.

1. Introduction

In 2007, the International Agency for Research on Cancer classified work as a firefighter as possibly carcinogenic based on findings of increased risks for non-Hodgkin's lymphoma, testicular cancer, and prostate cancer [1]. A meta-analysis published in 2019 reported significantly increased summary incidence risk estimates for cancers of the prostate, colon, rectum, testis, bladder, thyroid, pleura, and for cutaneous melanoma. Summary mortality risk estimates were significantly increased for rectal cancer and non-Hodgkin's lymphoma [2].

No certain causes of these increased risks are yet established, although occupational exposure to chemical carcinogens through fire smoke, soot, and debris would seem to be a plausible candidate [1]. Additional proposed relevant factors include diesel exhaust exposure [3] and shift work [4].

Assuming that occupational exposure affects firefighters' risk of cancer, this effect could differ between time periods because work

* Corresponding author. P.O. Box 5313, Majorstuen, 0304, Oslo, Norway.
E-mail address: jarle.jakobsen@kreftregisteret.no (J. Jakobsen).

2093-7911/$ – see front matter
https://doi.org/10.1016/j.shaw.2020.07.004

conditions for firefighters have been continually changing. Examples include new work tasks, development of new gear and protective equipment, and novel flammable materials producing fire smoke with carcinogens not previously encountered. Work conditions are also likely to differ geographically as flammable materials and firefighters' work tasks, techniques, and equipment may vary.

There is limited literature describing changes and developments in firefighters' work conditions in detail. One study [5] reviewed museum data and literature in an electronic library catalog to describe historical changes in chemical exposures for Danish firefighters since World War II. To the best of our knowledge, no other studies have systematically described historical work conditions related to carcinogen exposure in fire departments.

A fire may produce a large number of carcinogenic substances, including polycyclic aromatic hydrocarbons, volatile organic compounds, and persistent, bioaccumulative, and toxic substances [1]. The route of exposure may include inhalation, ingestion, or dermal exposure.

A firefighter's most important protection against inhalation of smoke and ingestion of soot is the self-contained breathing apparatus (SCBA). For smoke-diving operations, an open-circuit SCBA with either a positive or negative pressure system has normally been used. In a negative pressure system, the pressure inside the mask is negative relative to the surrounding air. Thus, smoke may leak into the mask if it does not fit perfectly to the wearer's face. A positive pressure system supplies a constant flow of gas to the mask, preventing inward leakage of smoke. Although the use of SCBAs is an integral part of smoke diving, firefighters have been reluctant to wear them during other parts of fighting a fire. The equipment is heavy and uncomfortable and can reduce vision and communication [6]. For these reasons, firefighters often have not worn their SCBAs during knockdown of fires (when fires are fought from outside of buildings) or overhaul (when flames are no longer visible, but hidden fires and smoldering material may still be present). Exposure to a substantial amount of carcinogenic fumes may still occur even though no smoke is visible [7].

The rest of the firefighter's personal protective equipment (PPE) is necessary for protection against heat and flames but also plays a part in preventing dermal exposure to carcinogens. The development of more heat- and fire-resistant clothing made from materials such as aramid polymers (e.g. Nomex, Kevlar) or polybenzimidazole (PBI) may enable firefighting activities closer to the fire, potentially leading to higher risk of exposure to combustion products. These materials also need to be treated with water repellents, a potential source of perfluoroalkyl acids (PFAAs). PFAAs are possible carcinogens [8] found to be present at increased levels in firefighters' serum [9,10].

Synthetic firefighting foams are another potential source of PFAAs. Firefighting foams are mainly used to suppress fires in flammable liquids. They coat the surface of the liquid, lowering the temperature and preventing contact with oxygen.

Recent studies [11,12] highlight the importance of proper cleaning of turnout gear as carcinogens can persist and accumulate in clothing, leading to continuous exposure outside of firefighting situations [13].

Live fire training also represents a possibility for carcinogen exposure, especially for training instructors [14]. An Australian study provided some evidence that instructors at a training facility for firefighters were at increased risks of overall cancer, testicular cancer, brain cancer, and cutaneous melanoma compared with the general population [15]. Different combustible materials used during live fire training can produce varying amounts of different carcinogens, including polycyclic aromatic hydrocarbons and volatile organic compounds [16,17].

Firefighters are not only tasked with fighting fires. Additional duties may include chemical diving and clean up, situations where exposure to carcinogens is possible.

Exhaust from fire engines, fire trucks, and other service vehicles may represent a source of occupational exposure to carcinogens. In 2012, the International Agency for Research on Cancer classified diesel exhaust as a carcinogen (group 1) and gasoline exhaust as a possible carcinogen (group 2B) to humans based on results from experiments on cultured cells and lab animals. In highly exposed humans, diesel exhaust increases the risk of lung cancer and may be associated with bladder cancer [18]. The amount of exhaust in fire stations can be reduced by installing exhaust removal systems and ensuring that there are no open passages for air between the apparatus bay and sleeping/living quarters [3,19].

At present, over 300 fire departments comprising around 12,500 firefighters provide fire services for the Norwegian population. Of these, around 3500 are professional firefighters, whereas the rest (around 70%) are part-time or volunteer firefighters [20]. Norway's 356 municipalities are each responsible for providing their own fire services, but many cooperate in intermunicipal fire departments. As each municipality is responsible for its own fire service, no national standards have been in place for turnout gear, equipment, vehicles, intake criteria, etc. Although laws regarding general work conditions (work hours, safety at work) are in place [21], they are not specific for firefighters. National guidelines regarding smoke diving and chemical diving were put in place in 1994 [22]. The guidelines suggest routines for live fire training, health and physical requirements for smoke and chemical divers, and use and handling of PPE and other equipment. The lack of national standards could lead to local differences between departments and variations in when changes in work conditions occurred (e.g. new equipment, new techniques, new tasks). Thus, Norwegian firefighters' historical risk of exposure to potential occupational carcinogens may be heterogeneous.

The aim of this study is to describe work conditions in Norwegian fire departments from 1950 until today, with special attention toward work conditions and practices that could influence exposure to occupational carcinogens. We base our description of work conditions on a survey carried out among Norwegian fire departments. A historical overview of how factors modifying exposure have changed could add nuanced information to exposure metrics for future epidemiological studies. Furthermore, any present unsafe practices can be identified and possibly mitigated.

2. Materials and methods

We developed a questionnaire to explore Norwegian fire departments' work conditions from 1950 to present, focusing on factors that may influence the risk of cancer in firefighters. A reference group contributed to the questionnaire development. The group comprised representatives from firefighters' unions, employers' organizations, the association of Norwegian Firefighters Fight Cancer, the Norwegian Directorate for Civil Protection, the Norwegian Labour Inspection Authority, and the Norwegian Cancer Society.

The questionnaire included 61 questions regarding work conditions in fire departments. Table 1 shows examples of topics covered. For each question, information was requested for every decade from 1950 until today. All answers were given in free text. Unclear, missing, or illogical answers were returned to the departments for clarification. We coded answers manually with help from the reference group for interpretation of responses.

In 2017 and 2018, we distributed the questionnaires to 21 selected Norwegian fire departments. We used purposive sampling with the intent to include as many of the largest professional fire

departments in Norway as possible, while also ensuring inclusion of all Norwegian geographic regions. An additional department heard about our research project and contacted us themselves, wanting to participate.

The departments appointed a person responsible for completing the questionnaire and staying in contact with our research group. Departments were otherwise free to use whichever method suited them in gathering answers for the questionnaire, e.g., interviews with retired firefighters, anniversary history books, local archives, newspaper clippings, etc.

Several departments consist of multiple fire stations, and we asked departments to provide answers for each station when necessary, e.g., whether exhaust removal systems were installed. For answers where a specific year of change other than 1960, 1970, 1980, and so on was stated, we rounded to the nearest decade.

For brevity, we only included answers from a selected subset of questions in this paper. The selection of topics included was based on the previous literature and our own judgment as to which factors might be most relevant for exposure to occupational carcinogens for firefighters. Furthermore, we chose to focus on changes occurring in fire departments' work conditions and, therefore, do not present results from questions with little temporal variation. The complete questionnaire, translated to English, can be found in Supplementary Digital Content (SDC 1, translated questionnaire), and responses to questions not discussed in the following sections can be requested from the corresponding author.

Table 1
Examples of topics included in the questionnaire.

Category	Examples of questions
Personal protective equipment	Type of SCBAs Use of SCBAs during knockdown Use of SCBAs during overhaul Turnout gear Treatment of turnout gear with water repellents
Techniques and equipment	Ventilating fans Firefighting foams
Handling and cleaning of contaminated PPE and other gear	Washing of turnout gear Washing of other gear Transport of used gear and clothing
Live fire training	Regularity of live fire training Flammable materials used during live fire training
Work organization	Chemical diving
Vehicles and exhaust	Number of petrol-driven cars Number of diesel-driven cars Exhaust removal systems Open air passage between engine room and sleeping/living quarters

SCBAs = self-contained breathing apparatuses.

3. Results

Six of the invited 21 departments declined to participate. Sixteen departments (15 invited + 1 self-selected) answered the questionnaire. The number of stations in use by the departments ranged from 34 in the 1950s to 46 in the 2010s.

3.1. Personal protective equipment

Ten of 16 departments (63%) were smoke diving in the 1950s (Fig. 1A). The SCBAs used in smoke diving were negative pressure systems until the 1980s, except for one department using manual positive pressure in the 1960s and 1970s. Regular use of SCBAs during knockdown of fires from outside of buildings started after 1990 (Fig. 1B). Today, 12 of 16 departments (75%) use SCBAs regularly in this phase of firefighting. A similar trend was found for the use of SCBAs during overhaul (Fig. 1C), with no department using SCBAs regularly before the 2000s.

Until the 1970s, the departments' other personal protective equipment generally consisted of raincoats and/or woollen overalls paired with rubber boots and gloves. Five departments (31%) used

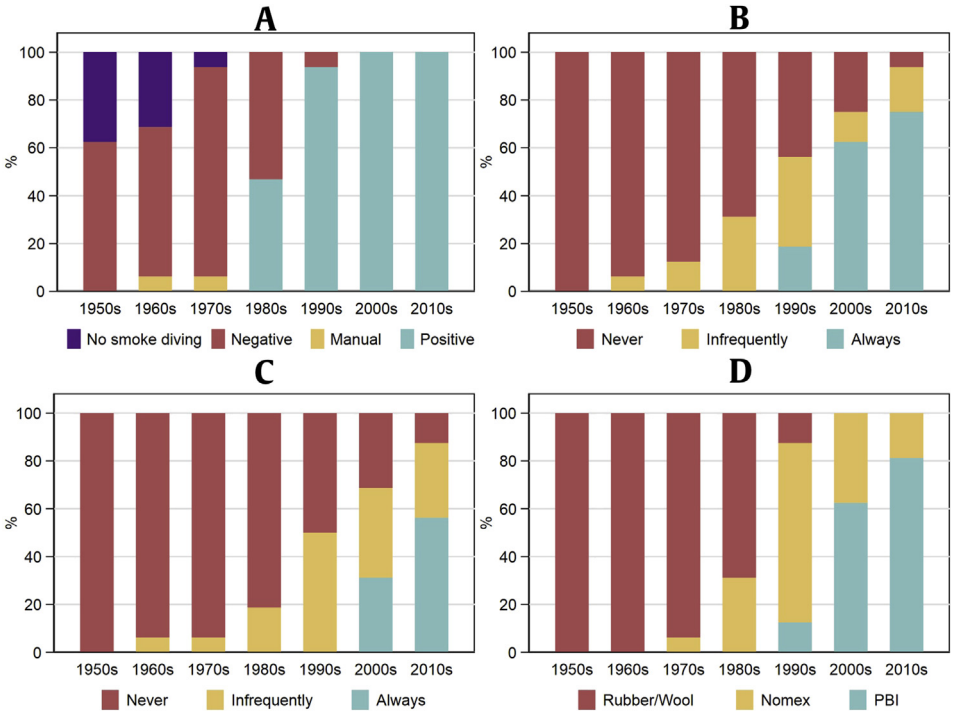

Fig. 1. A) The type of self-contained breathing apparatuses (SCBAs) used during smoke diving. (B) Use of SCBAs during knockdown of fires from outside of buildings. (C) Use of SCBAs during overhaul. (D) Turnout gear materials. n = 16 departments.

clothes made of Nomex in the 1980s, whereas PBI became the preferred material for firefighter clothing during the 2000s (Fig. 1D).

3.2. Handling and cleaning of contaminated PPE and other gear

Answers to questions on cleaning of turnout gear, cleaning of other gear, and handling of used equipment during transport back to the station are presented in Fig. 2. A marked shift occurred around 2010 concerning handling and cleaning of contaminated turnout gear. For all except one department, there were no set standards for cleaning of turnout gear until 2000. Today, every department respond that turnout gear is to be washed after each use in a contaminated environment (Fig. 2A). Similar results were found for the transport of used gear. Before 2000, no department had routines for transport of used clothing and equipment from a fire scene, meaning the firefighters wore their used turnout gear during transport back to the station. Today, all departments respond that used turnout gear is to be doffed at the fire scene and that used clothing and gear should be transported back to the station in plastic bags and/or a designated compartment of the fire engine (Fig. 2B). Used equipment (hoses, SCBAs, axes, etc.) was previously more likely to be washed than turnout gear (Fig. 2C). Seven of 16 departments (44%) regularly cleaned used equipment after a fire in the 1970s. Similar to used turnout gear, all departments now wash used equipment after each fire.

About half of the departments treated turnout gear with water repellents in the 1990s and 2000s (7 of 16 (44%) and 9 of 16 (56%), respectively, Fig. 2D). Today, 13 of 16 departments (81%) regularly treat turnout gear with water repellents.

3.3. Techniques and equipment

Synthetic firefighting foams were introduced in the 1950s and 1960s but became more widespread in the 1980s and 1990s (Fig. 3A). Only one department used fans to ventilate smoke and hot air during the early stage of a fire in the 1970s (Fig. 3B). Ventilating fans were introduced to the remaining 15 departments during the 1980s and 1990s.

3.4. Live fire training

All the fire departments have performed regular live fire training since the 1990s at the latest, whereas only one report certainly doing so in the 1950s (Fig. 3C). Fig. 3D shows the proportion of departments burning plywood or other glue-containing wooden material, rubber tires, vehicles, foam rubber, or general junk during live fire training. The use of these materials was not common before 1980, while in the 1990s, 11 departments (69%) used at least one of these materials.

3.5. Work organization

Nine of 16 departments (56%) report currently performing chemical diving/chemical clean up after accidents (Supplementary Fig. S1). Most of these (seven of nine) started performing these tasks in the 1980s or 1990s.

3.6. Vehicles and exhaust

Supplementary Fig. S2 shows the proportions of diesel- and petrol-driven vehicles used by the departments. The proportions of diesel-driven vehicles were 13%, 21%, 44%, 65%, 73%, 84%, and 96% in the 1950s, 1960s, 1970s, 1980s, 1990s, 2000s, and 2010s, respectively. The number of vehicles in use increased from 97 in the 1950s to 250 today. Supplementary Fig. S3A shows the proportion of fire stations with an exhaust removal system installed. Only one station had an (partially functioning) exhaust removal system installed in the 1950s, while 29% (13 of 45 stations) and 41% (19 of 46 stations) had one in the 1980s and today, respectively. Today,

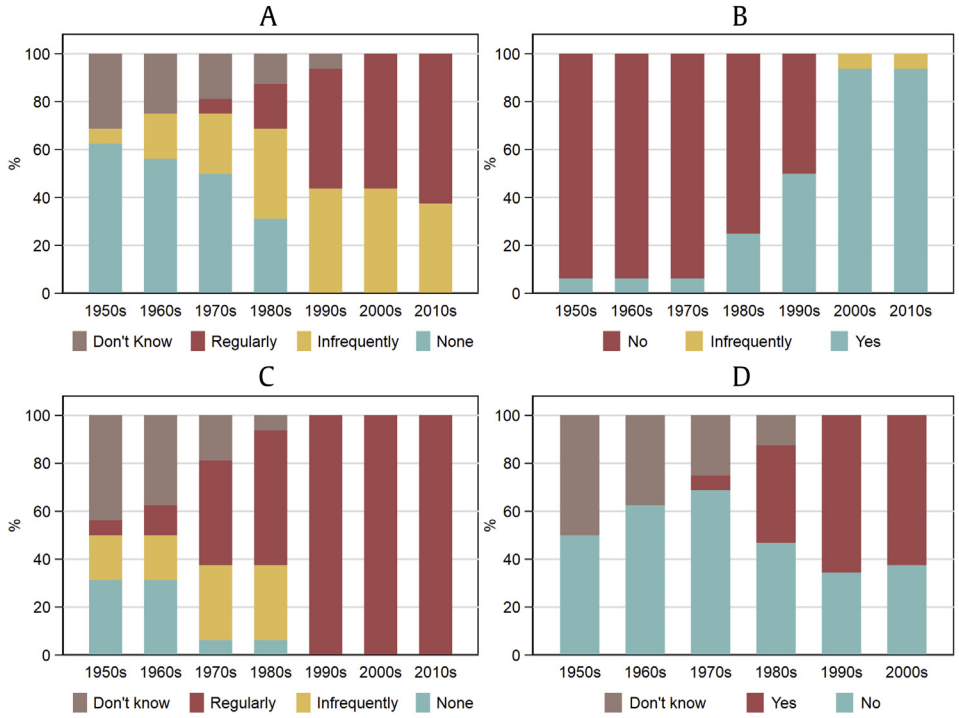

Fig. 2. A) Routines for cleaning of turnout gear. (B) Routines for cleaning of other gear. (C) Transport of turnout gear back to the station. (D) Treatment of turnout gear with water repellents. n = 16 departments.

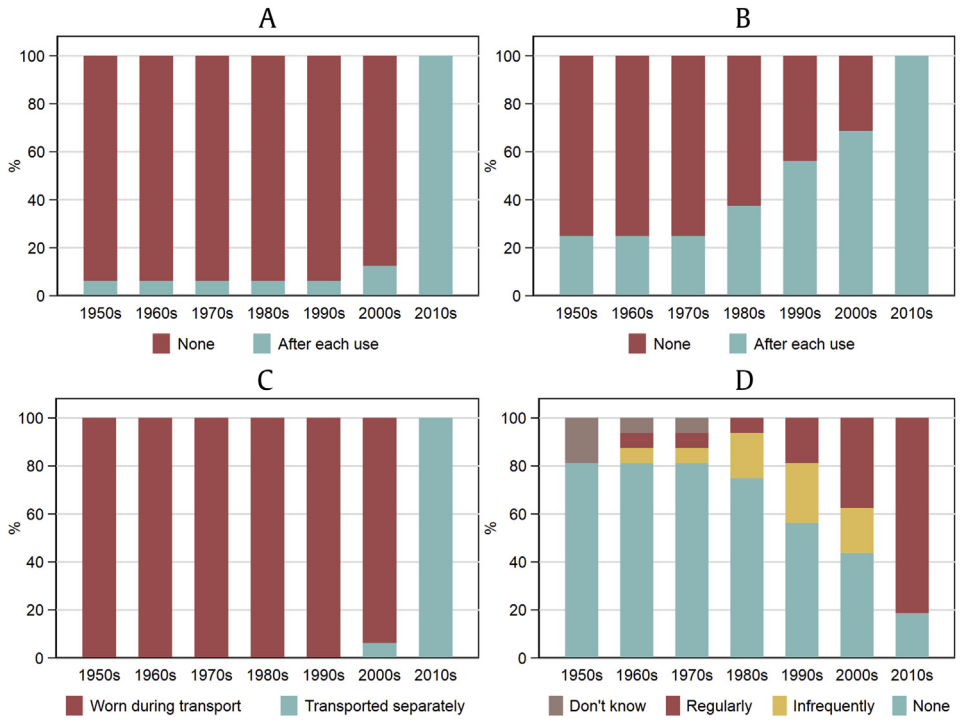

Fig. 3. A) Use of synthetic firefighting foams. (B) Use of ventilating fans during firefighting. (C) Live fire training. (D) Use of plywood, tires, vehicles, foam rubber, and/or general junk as flammable material in live fire training. n = 16 departments.

21% (8 of 39) of stations with living and/or sleeping quarters have a potentially open air passage from the apparatus bay to these quarters (Supplementary Fig. S3B). This proportion was 60% (18 of 30) and 50% (19 of 38) in the 1960s and 1980s, respectively.

4. Discussion

We identified many changes in the Norwegian fire departments' work conditions from the 1950s until today with implications for carcinogen exposure.

Better equipment, such as positive pressure SCBAs and turnout gear with an outer layer made of Nomex or PBI, gives firefighters the opportunity to fight fires more aggressively, potentially leading to higher exposure to fire smoke and soot. The benefits of positive as compared with negative pressure SCBAs, and the recent use of SCBAs in all phases of firefighting, including knockdown and overhaul, may offset this increased risk of exposure. Our opinion is that the introduction of positive pressure SCBAs and the improved use of SCBAs in all phases of firefighting are the most important protective factors identified in our study. Furthermore, routines implemented around 2010 regarding the handling and cleaning of used gear should mark a reduction in exposure to potential carcinogens. The technique of using ventilating fans to control smoke and hot air can also reduce exposure.

Our study identified two possible sources of exposure to PFAAs outside of combustion products, namely water repellents and firefighting foams. In 2007, the EU and Norway placed a ban on the production of perfluorooctane sulfonate–containing products [23]. It is also illegal to own or keep perfluorooctane sulfonate–containing products in Norway. This should reduce Norwegian firefighters' exposure to this common PFAA.

Live fire training became more common during the last half of the 20th century. This represents an increase in potential exposure to fire smoke and soot, especially for training instructors. However, the last couple of decades seem to mark a change toward use of flammable materials producing fewer carcinogens, and this could alleviate some of this increase in exposure.

A clear shift toward more diesel-powered vehicles, and therefore increased exposure to carcinogens in diesel exhaust, represents a potential risk for Norwegian firefighters. However, increasingly strict regulations have been put in place to reduce the emissions of particulate matter from diesel-powered vehicles. From 2008, a particle filter is required in all new diesel-powered vehicles in Norway [24]. Another way to reduce particulate matter in diesel exhaust is to reduce the level of sulfur in diesel. The EU, including Norway, has mandated a progressively lower sulfur content in diesel since the early 21st century [25]. Furthermore, the introduction of exhaust removal systems and airtight doors between the apparatus bay and other areas of the fire station should limit the amount of exposure occurring at the station.

Fig. 4 summarizes the changes we identified regarding work conditions with implications for exposure to potential occupational carcinogens in Norwegian fire departments from 1950 until today. Factors assumed to increase exposure to carcinogens were generally introduced earlier than those assumed to decrease exposure, but a sizeable number of positive changes have occurred during the last couple of decades.

Our findings indicate that although there are variations between different Norwegian fire departments, the overarching trends in work conditions are similar throughout the country. Focusing on department-specific work conditions, a peak risk of carcinogen exposure may have occurred during the 1970s and 1980s, while several recent changes hopefully means that today's firefighters are at a markedly reduced exposure level.

This study focused on work conditions for professional firefighters, and we distributed the questionnaire primarily to fire departments in the biggest cities of Norway, while ensuring that departments from all geographic regions (North, Middle, West, South, and East) participated. Although the 16 departments included is a small number compared with the over 300

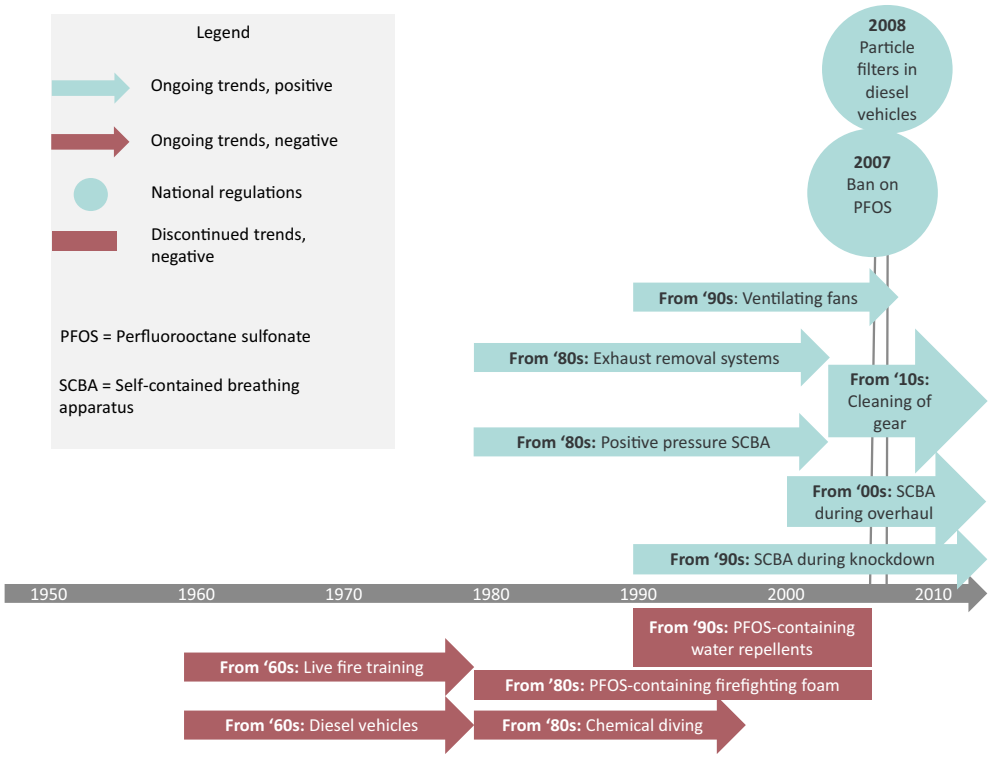

Fig. 4. Timeline summarizing changes occurring in Norwegian fire departments' work conditions from 1950 until today.

departments in Norway, they provide fire services for 48% of the Norwegian population as of 2019. However, around 70% of the Norwegian fire services currently consist of part-time employees and volunteers [20]. It is likely that smaller, rural fire departments with fewer resources have been slower than the larger fire departments included in our survey to implement new routines, equipment, or techniques. Our study may therefore not accurately describe the changes in work conditions in departments consisting mainly of part-time or volunteer firefighters.

Six departments declined to participate in our survey, while one department contacted us themselves for inclusion. The current survey is part of a larger research project about cancer risk in Norwegian firefighters. This project also includes establishing a cohort of firefighters. The departments declining to participate did so because of lack of time and/or resources to commit to this cohort establishment. We have no reason to believe that these departments would have answered our questionnaire differently than the participating departments. We therefore believe that selection bias is limited.

We consider the extensive amount of information gathered from the largest fire departments in Norway to be the main strength of this study. The reference group has helped with interpreting responses and controlled for inconsistencies and illogical answers. Missing, unclear, or illogical answers were returned to the departments for clarification. We therefore regard the answers to be as complete as possible. A limitation to our findings is that some departments had trouble remembering or finding data for some questions from the earliest decades. A form of recall bias may also be present in our study, as there have been increased focus on the carcinogenicity of firefighting the last few years. Norwegian firefighters have been awarded compensation for cancer as occupational disease [26]. This could lead departments to exaggerate the extent of previously suboptimal work conditions.

In this study, we only gathered self-reported information from fire departments on department-specific work conditions. We did not gather information on numbers or types of fires encountered, nor did we obtain information on types and amount of flammable materials encountered outside of live fire training. If occupational exposure to fire smoke, soot, and debris causes increased cancer risk in firefighters, the risk may be more dependent on the types of carcinogens from different flammable materials than any department-specific work conditions. It is beyond the scope of this article to report how building materials and materials used in inventory and vehicles have changed from 1950 until present in Norway.

Few systematic descriptions of historical work conditions for firefighters makes comparisons of our findings with international literature difficult. Findings by Pedersen [5] in Denmark differ somewhat from ours. Notably, obligatory use of SCBAs during both knockdown and overhaul was introduced as early as the 1970s in Denmark, while this became common in Norway around 2000. Exhaust removal systems were fully implemented in Danish fire departments in the early 2000s, whereas under half of the stations included in our study have an exhaust removal system installed today. Assignment to chemical clean-ups seems to have occurred earlier in Denmark (early 1970s) than in Norway (1980s and 1990s). These differences show that work conditions may vary geographically, even between countries as similar as Denmark and Norway.

Today, firefighters are increasingly aware of the association between firefighting and increased risk of cancer [27,28]. Attitudes regarding clean gear and use of SCBAs are changing [29]. Furthermore, changes mirroring our findings seem to be taking place internationally, including immediately doffing contaminated equipment after use, transporting it in special compartments of vehicles, washing and cleaning gear after each use, and wearing SCBAs until the completion of overhaul [30]. Thus, some of the trends found in our survey among Norwegian fire departments may apply to other developed countries. However, because work practices and techniques for firefighters are likely intrinsically linked to local conditions, we advise against broadly generalizing our results.

Limited evidence exists linking the topics discussed in this article with risk of cancer in firefighters. As we have no quantitative data on how the work conditions discussed in this paper affect carcinogen exposure, the topics addressed in this paper represent our opinions as to how work conditions in fire departments are relevant for carcinogen exposure. A full exposure assessment would need quantitative data on how each of the discussed factors influence carcinogen exposure. However, such data on historical work conditions are lacking, and gaining these measurements through future research may prove challenging because of ethical and practical limitations. Thus, qualitative information on work conditions and practices can contribute to the understanding and assessment of carcinogenic exposures related to firefighting and is an important supplement to quantitative measurements such as air samples or blood and urine tests. Further research is needed to evaluate whether firefighters' risk of cancer changes with changes in work conditions and to clarify which protective efforts are effective.

5. Conclusion

This study marks the first attempt at describing work conditions and practices in fire departments relevant for carcinogen exposure with the help of systematic information gathering directly from fire departments.

Fire departments' work conditions change over time, and this can affect firefighters' carcinogen exposure. Our findings suggest that work conditions in Norwegian fire departments produced a peak risk of carcinogen exposure in the 1970s and 1980s, before changes implemented in the last few decades may have reduced exposure. Exposure is also likely to differ by external work conditions not included in our survey (e.g., number and types of fires, combustible materials encountered).

Sources of funding

The corresponding author's (JJ) research position is funded by a grant from the Dam Foundation (grant number 2019/FO247424). Our research project on cancer in firefighters is financed by the Gjensidige Foundation, the Norwegian Union of Municipal and General Employees, the Norwegian Confederation of Trade Unions, the Norwegian Cancer Society, Oslo Brannkorpsforening, Norwegian Firefighters Fight Cancer, and the Norwegian Labour Inspection Authority.

Conflicts of interest

Members from several of our funding sources (the Norwegian Union of Municipal and General Employees, the Norwegian Confederation of Trade Unions, the Norwegian Cancer Society, Oslo Brannkorpsforening, Norwegian Firefighters Fight Cancer and the Norwegian Labour Inspection Authority) were part of our reference group, and thus contributed to the design of the questionnaire and interpretation of the responses. They have however not taken part in the writing of this manuscript, and no approval from these organizations were sought before submitting for publication. The authors declare no other conflicts of interest.

Acknowledgments

We would like to thank the participating fire departments for the work they put into completing the questionnaire. Thanks to the members of our reference group for assisting in making the questionnaire, and interpreting and categorizing responses. Thanks to Line Solhaug (research assistant, Cancer Registry of Norway) for help with data collection. Thanks to Elisabeth Jakobsen (Head of communications, Cancer Registry of Norway) for help with designing Fig. 4.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.shaw.2020.07.004.

References

[1] International Agency for Research on Cancer. Painting, firefighting and shiftwork. IARC monographs on the evaluation of carcinogenic risks to humans, vol. 98. Lyon, France: IARC; 2010.
[2] Jalilian H, Ziaei M, Weiderpass E, Rueegg CS, Khosravi Y, Kjaerheim K. Cancer incidence and mortality among firefighters. Int J Canc 2019;145(10):2639–46.
[3] Sparer EH, Prendergast DP, Apell JN, Bartzak MR, Wagner GR, Adamkiewicz G, Hart JE, Sorensen G. Assessment of ambient exposures firefighters encounter while at the fire station: an exploratory study. J Occup Environ Med 2017;59(10):1017–23.
[4] International Agency for Research on Cancer. IARC monographs volume 124 group. Carcinogenicity of night shift work. Lancet Oncol 2019;20:1058–9.
[5] Pedersen JE, Petersen KU, Hansen J. Historical changes in chemical exposures encountered by Danish firefighters. Scand J Work Environ Health 2019;(3):248–55.
[6] Park H, Park J, Lin S-H, Boorady LM. Assessment of Firefighters' needs for personal protective equipment. Fash Text 2014;1(1):8.
[7] Bolstad-Johnson DM, Burgess JL, Crutchfield CD, Storment S, Gerkin R, Wilson JR. Characterization of firefighter exposures during fire overhaul. AIHA J 2000;61(5):636–41.
[8] Lau C, Anitole K, Hodes C, Lai D, Pfahles-Hutchens A, Seed J. Perfluoroalkyl acids: a review of monitoring and toxicological findings. Toxicol Sci 2007;99(2):366–94.
[9] Jin C, Sun Y, Islam A, Qian Y, Ducatman A. Perfluoroalkyl acids including perfluorooctane sulfonate and perfluorohexane sulfonate in firefighters. J Occup Environ Med 2011;53(3):324–8.
[10] Laitinen JA, Koponen J, Koikkalainen J, Kiviranta H. Firefighters' exposure to perfluoroalkyl acids and 2-butoxyethanol present in firefighting foams. Toxicol Lett 2014;231(2):227–32.
[11] Fent KW, Alexander B, Roberts J, Robertson S, Toennis C, Sammons D, Bertke S, Kerber S, Smith DL, Horn GP. Contamination of firefighter personal protective equipment and skin and the effectiveness of decontamination procedures. J Occup Environ Hyg 2017;14(10):801–14.
[12] Mayer AC, Fent KW, Bertke S, Horn GP, Smith DL, Kerber S, La Guardia MJ. Firefighter hood contamination: efficiency of laundering to remove PAHs and FRs. J Occup Environ Hyg 2019;16(2):129–40.
[13] Fent KW, Evans DE, Booher D, Pleil JD, Stiegel MA, Horn GP, Dalton J. Volatile organic compounds off-gassing from firefighters' personal protective equipment ensembles after use. J Occup Environ Hyg 2015;12(6):404–14.
[14] Fent KW, Toennis C, Sammons D, Robertson S, Bertke S, Calafat AM, Pleil JD, Wallace MAG, Kerber S, Smith DL, Horn GP. Firefighters' and instructors' absorption of PAHs and benzene during training exercises. Int J Hyg Environ Health 2019;222(7):991–1000.
[15] Glass DC, Del Monaco A, Pircher S, Vander Hoorn S, Sim MR. Mortality and cancer incidence at a fire training college. Occup Med 2016;66(7):536–42.
[16] Laitinen J, Makela M, Mikkola J, Huttu I. Fire fighting trainers' exposure to carcinogenic agents in smoke diving simulators. Toxicol Lett 2010;192(1):61–5.
[17] Fent KW, Mayer A, Bertke S, Kerber S, Smith D, Horn GP. Understanding airborne contaminants produced by different fuel packages during training fires. J Occup Environ Hyg 2019;16(8):532–43.
[18] International Agency for Research on Cancer. Diesel and gasoline engine exhausts and some nitroarenes. IARC monographs on the evaluation of carcinogenic risks to humans, vol. 105. Lyon, France: IARC; 2010.
[19] Michalak G. Diesel emissions in fire stations [R.I.C.H.T.E.R. Foundation web site]; July 21, 2004. Available at: http://www.richter-foundation.org/pdf/case-study1.pdf. [Accessed 2 March 2020].
[20] Det store brannløftet. Om oss – Brannløftet [The Gjensidige Foundation web site]; November 19, 2019. Available at: http://brannloftet.no/om-oss/.
[21] Working Environment Act 2005. Act relating to working environment, working hours and employment protection, etc. Available at: https://lovdata.no/dokument/NLE/lov/2005-06-17-62. Accessed August 10, 2020.
[22] The Norwegian Directorate for Civil Protection. Veiledning om røyk- og kjemikaliedykking. Tønsberg, Norway: DSB. 2005. Available at: https://www.dsb.no/lover/brannvern-brannvesen-nodnett/veiledning-til-forskrift/veiledning-om-royk–og-kjemikaliedykking/. [Accessed 2 March 2020].
[23] Directive 2006/122/EC of the European Parliament and of the Council of 12 December amending for the 30th time Council Directive 76/769/EEC on the approximation of the laws, regulations and administrative provisions of the Member States relating to restrictrions on the marketing and use of certain

dangerous substances and preparations (perfluorooctane sulfonates). Off J 2006:32–4. L372.
[24] Regulation (EC) No 715/2007 of the European Parliament and of the Council of 20 June 2007 on type approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information. Off J 2007:1–16. L171.
[25] Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC. Off J 2009;140:88–113.
[26] Tømmerås O. Gjennombrudd for brannmenn – prostatakreft er nå godkjent som yrkesskade [Fagbladet web site]; December 12, 2017. Available at: https://fagbladet.no/nyheter/gjennombrudd-for-brannmenn–prostatakreft-er-na-godkjent-som-yrkesskade-6.91.518212.60df9639ee. [Accessed 2 March 2020].
[27] Schaefer Solle N, Caban-Martinez AJ, Levy RA, Young B, Lee D, Harrison T, Kobetz E. Perceptions of health and cancer risk among newly recruited firefighters in South Florida. Am J Ind Med 2018;61(1):77–84.
[28] Anderson DA, Harrison TR, Yang F, Wendorf Muhamad J, Morgan SE. Firefighter perceptions of cancer risk: results of a qualitative study. Am J Ind Med 2017;60(7):644–50.
[29] Harrison TR, Muhamad JW, Yang F, Morgan SE, Talavera E, Caban-Martinez A, Kobetz E. Firefighter attitudes, norms, beliefs, barriers, and behaviors toward post-fire decontamination processes in an era of increased cancer risk. J Occup Environ Hyg 2018;15(4):279–84.
[30] Caffee B. Firefighter Occupational Cancer Risk Adjustment; 2015. Available at: https://shareok.org/bitstream/handle/11244/317742/Caffee_okstate_0664M_15651.pdf?sequence=1&isAllowed=y. [Accessed 2 March 2020].