Mount Sinai

OCCUPATIONAL CANCER IN NEW YORK CITY FIREFIGHTERS

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A WORLD HEALTH ORGANIZATION
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EXECUTIVE SUMMARY

Firefighters in New York City and across the United States are exposed in their work to an extraordinary variety of chemical carcinogens. These exposures include benzene, formaldehyde, polycyclic aromatic hydrocarbons (PAH), asbestos and the complex mix of carcinogenic products that arise from combustion of synthetic and plastic materials. The modern fire environment is far more complex than that of 50 years ago, because of the introduction to the marketplace in recent decades of more than 70,000 synthetic chemicals, the majority of which have never been tested for their possible toxic effects.

This report, assembled by investigators from the Mount Sinai School of Medicine under the guidance of a distinguished Advisory Committee, summarizes the available information on the carcinogenic hazards encountered in firefighting and presents the results of epidemiologic studies of cancer in firefighters.

The following specific linkages have been established between cancer and chemicals encountered in firefighting:

- Leukemia is caused by benzene and 1,3-butadiene.
- Lymphoma and multiple myeloma are caused by benzene and 1,3-butadiene.
- Skin cancer is caused by soot containing PAH.
- Genitourinary tract cancer is caused by gasoline and PAH.
- Gastrointestinal cancer is caused by PCBs and dioxins.
- Angiosarcoma of the liver and brain cancer are caused by vinyl chloride.

Leukemia, lymphoma, multiple myeloma, cancer of the genitourinary tract, prostate cancer, gastrointestinal cancer, brain cancer and malignant melanoma are among the cancers that have been observed consistently with increased frequency in epidemiologic studies of firefighters. We believe that the full scope of the occupational cancer hazard to firefighters has not yet been defined. It is likely in the future that additional associations will be identified between chemicals encountered in the fire environment and cancer in firefighters. Nevertheless, the available data are sufficient to conclude that excess risk of cancer is a distinct hazard of firefighting.

Firefighters in New York City are heavily exposed to carcinogenic chemicals in their work because of the nature of buildings in New York City, the density of these buildings and their high-rise structure. In accord with the growing number of studies from around the country of the cancer risks to firefighters, we conclude that firefighters in New York City are at excess risk of occupational cancer.

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The physicians and medical scientists listed here have generously reviewed our report and have provided their comments and advice. We are thankful to them.

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This report represents the professional opinions of the authors and reviewers and not necessarily those of the institutions listed.

A. INTRODUCTION

Firefighting is an extraordinarily dangerous occupation. It involves exposures to toxic chemical and physical agents in concentrations that are unparalleled in any other workforce. The acute hazards of firefighting include burns, smoke inhalation, carbon monoxide poisoning, asphyxiation, falls and trauma. Acute lung injury is common. According to the U.S. Department of Labor, the rate of job-related deaths among active duty firefighters is 11.3 per 100,000, thus making firefighting the third most fatal occupation in the United States.

Chronic diseases, cancer among them, are also recognized hazards in firefighting. Firefighters are repeatedly exposed in their work to high levels of many carcinogens (chemicals with the potential to cause cancer). These carcinogens include benzene, formaldehyde, polycyclic aromatic hydrocarbons (PAH), asbestos and the carcinogenic products that arise from combustion of complex synthetic and plastic materials.

Leukemia, lymphoma, multiple myeloma, cancer of the genitourinary tract, prostate cancer, gastrointestinal cancer, brain cancer and malignant melanoma are among the cancers that have been observed with increased frequency in epidemiologic studies of firefighters. Although the full scope of the occupational cancer hazard to firefighters has not yet been defined, it is clear that cancer caused by occupational exposures to toxic chemicals is a uniquely important problem among firefighters.

In this report, investigators from the Mount Sinai School of Medicine of the City University of New York examine the risk of cancer among firefighters and its relevance for New York City firefighters. The report begins by discussing the nature of cancer. It reviews the literature on the chemical causation of cancer. It summarizes data on the chemical carcinogens encountered in firefighting. It reviews the epidemiological literature on cancer among firefighters. Finally, it concludes by summarizing the available evidence on the carcinogenic hazards of firefighting in New York City.

B. CANCER RISKS ASSOCIATED WITH OCCUPATIONAL EXPOSURE IN FIREFIGHTING

B.1. THE NATURE OF CANCER

Cancer is characterized by uncontrolled growth and chaotic multiplication of cells in the human body. Cancerous cells have lost their normal ability to stop growing and dividing. They do not mature and become stable, and they do not respond to messages from other cells and organs. The essence of cancer is uncontrolled cell growth.

Each case of cancer is believed by medical scientists to originate from a single cell. The many hundreds of thousands of cells that comprise a fully developed cancer are believed to all be descendants of a single cell that has gone awry and undergone malignant transformation.

The creation of a cancerous cell is a stepwise process, a transformation that usually requires many years and cell cycles. Each step in the process consists of a mutation, a change in the DNA, the basic genetic material that is present in each cell in the human body. The development of a malignant cancer requires a series of mutations.

Many factors can trigger the initial mutation. These include chemical carcinogens as well as physical agents. In some cases the initial mutation appears to arise spontaneously, perhaps because of an inherited predisposition.

The initial mutation is a necessary step on the pathway to cancer, but by itself it is not sufficient to cause cancer. A series of additional mutations are required before initiated cells and their descendants actually become cancerous. These additional mutations make cells and their descendants more and more unstable, and they bring about progressive increases in the rate of cell growth. A common sequence is that the initial mutation activates a type of gene called an oncogene. This activation of the oncogene results in increased production of cellular growth factors that cause cells to grow at a rapid rate. When cells are growing too rapidly and undergo division at an accelerated pace, the likelihood of a second mutation increases. The second mutation frequently consists of the deactivation of a suppressor gene, a gene that normally slows the growth of cells. When an oncogene has been activated and a suppressor gene turned off, the effect is similar to that of a car running down hill without its brakes and with the accelerator held down by a brick.

At this point, with the affected cells multiplying much too rapidly, the cells become highly susceptible to still further changes in their genetic material. The cell becomes more and more independent and no longer responds to messages that it may receive from the cells around it. Finally, the evolving cancer cell becomes totally independent and fully capable of multiplying chaotically. At this point, a true cancer exists. The cells have become malignant.

Once a true cancer has developed, the malignant cells can metastasize, that is, they can spread from the initial site of the cancer to other distant areas of the body where they may invade tissues and cause secondary cancers. For example, cancers of the intestine frequently metastasize to the liver. Cancers of the lung may metastasize to the brain. When cancer has become metastatic it usually responds poorly to treatment.

In recent years, enormous amounts of new information on malignant transformation and on the processes involved in the development of cancer have been provided by the tools of molecular biology. We now understand a great deal more about the steps in the evolution of human cancer than we did even five or ten years ago. The prospects are very real that it will be possible in the not too distant future to identify human cancer before it has become fully malignant.

B.2. OCCUPATIONAL EXPOSURES CAN CAUSE CANCER

Chemicals are highly pervasive in the modern world. Since World War II, astronomic increases in the variety and production volumes of synthetic chemicals have occurred. Today more than 70,000 distinct chemicals are used commercially in the United States and are registered with the U.S. Environmental Protection Agency. Approximately 1,000 new chemicals are registered each year. These chemicals are combined into more than 7 million mixtures, formulations and blends that are found in homes, public buildings and workplaces across the United States.

Testing of chemicals for their carcinogenic and other toxic effects has not kept pace with chemical production. Despite decades of concern about the toxic effects of chemical substances, the toxic effects of most of the chemicals currently in commercial use have never been evaluated. A study by the U.S. National Academy of Sciences found that no information was available on the carcinogenicity and other toxicity of approximately 80% of the chemicals in industrial use. Even for those classes of chemicals about which most is known--food additives and drugs--reasonably complete information on toxicity is available for only a fraction.

The absence of toxicity data on the majority of chemicals in commercial use means that firefighters are exposed on a daily basis to chemicals with unknown effects. It is quite likely, therefore, that in addition to their exposures to known carcinogens, firefighters experience exposures to carcinogenic chemicals whose cancer-causing potential has not yet been identified.

History of Chemical Carcinogenesis in Humans. The first recognition that toxic chemicals in the workplace could cause human cancer was the report in 1775 by Sir Percival Pott, a London surgeon, of an excess incidence of cancer of the scrotum among young chimney sweeps in London. Pott attributed those tumors to the chimney sweeps' exposure to soot. Later studies confirmed Pott's observation and demonstrated that the chemical agents in soot responsible for scrotal cancer were polycyclic aromatic hydrocarbons (PAH). Firefighters in New York City are regularly exposed to these chemicals in soot and smoke.

A second early study of chemical carcinogenesis was the report by Rehn, a Swiss-German surgeon, who in 1895 noted a high frequency of cancer of the urinary bladder among chemical workers involved in the production of synthetic aniline dyes. Those chemicals are encountered today by firefighters in fighting chemical fires.

In recent decades, causal associations with cancer have been noted for the following chemicals:

- Benzene causes leukemia and lymphoma.
- Asbestos causes lung cancer, malignant mesothelioma and cancer of the larynx.
- Arsenic causes cancer of the skin, lung and liver.
- Bis(chloromethyl)ether causes lung cancer.
- Vinyl chloride monomer causes angiosarcoma of the liver and brain cancer.
- Formaldehyde causes cancer of the lung and nasal sinuses.
- 1,3-butadiene causes leukemia and lymphoma.

Current Status of Chemical Carcinogenesis in Humans. In 1987, the International Agency for Research on Cancer (IARC), the cancer agency of the World Health Organization, published a list of chemicals and industrial processes for which there exists clear and proven evidence of human carcinogenicity. IARC identified 25 chemicals that have unequivocally been shown to cause cancer in humans (Table 1). Additionally, IARC identified a number of chemicals for which there is definite animal evidence of carcinogenicity but only limited or inadequate human evidence (Tables 2 and 3). IARC advised that in the absence of adequate data on humans, "it is reasonable for practical purposes to regard chemicals for which there is sufficient evidence of carcinogenicity in animals as though they represent a carcinogenic risk to humans."

The U.S. National Institute for Occupational Safety and Health (NIOSH) calculated on the basis of the decennial National Occupational Exposure Survey that more than 7 million American workers have the potential for regular occupational exposure to proven human carcinogens. Firefighters are among these workers.

Investigators from the Mount Sinai School of Medicine have previously estimated that 10 per cent of all cancer deaths in New York State are due to occupational exposures. Work-related cancer among firefighters, however, is under-diagnosed. Many cancers that are work-related are mistakenly attributed to "lifestyle factors," old age, or to other poorly defined factors.

TABLE 1.-- Chemical exposures causally associated with human cancer*

Occupational exposure	Cancer site
4-Aminobiphenyl	Bladder
Arsenic and arsenic compounds	Lung, skin, liver, angiosarcoma
Asbestos	Pleura and peritoneum (mesothelioma), lung, larynx, gastrointestinal tract, kidney
Benzene	Leukemia and lymphoma
Benzidine	Bladder
Beryllium and beryllium compounds	Lung
Cadmium and certain cadmium compounds	Lung, prostate
Bis(chloromethyl)ether	Lung (mainly oat cell)
Chromium compounds, hexavalent	Lung
Coal tar pitches	Skin, scrotum, lung, bladder
Coal tars	Skin, scrotum, lung, bladder
Ionizing radiation	Leukemia, skin, other
Mineral oils, untreated and mildly treated	Skin, scrotum, lung
Mustard gas	Lung
ß-Naphthylamine	Bladder
Nickel and nickel compounds	Lung, nasal sinuses
Radium	Bone (sarcomas)
Radon	Lung
Shale oils	Skin, scrotum
Soots, tars, and oils	Skin, lung, bladder
Talc containing asbestiform fibers	Lung, mesothelioma
Ultraviolet radiation	Skin
Vinyl chloride	Liver (angiosarcoma), brain, lung

*From International Agency for Research on Cancer (IARC), 1987.

TABLE 2.-- Probable occupational carcinogens: limited evidence of human carcinogenicity, but proven carcinogenicity in animals*

Occupational exposure	Cancer site
Acrylonitrile	Lung
Benzo(a)pyrene	Lung, skin, bladder
Creosotes	Skin, scrotum
Dimethyl sulfate	Larynx
Ethylene oxide	Leukemia
Formaldehyde	Nasal cavity, nasopharynx, lung
Polychlorinated biphenyls	Liver
Silica (crystalline)	Lung
1, 3-Butadiene	Lymphoma, leukemia

*From IARC, 1987.

TABLE 3. --Possible occupational carcinogens: inadequate evidence of human carcinogenicity, but proven carcinogenicity in animals*

Occupational exposure	Animal	Human
Acetaldehyde	Nasal mucosa, larynx	
Carbon tetrachloride	Liver	
Chloroform	Liver, kidney	
Chlorophenols and phenoxyacetic acid herbicides		Soft tissue sarcoma and lymphoma
Chlorophenothane (DDT)	Liver, lung, lymphoma	
1,2-Dibromo-3-chloropropane (DBCP)	Nasal cavity, lung, stomach	
p-Dichlorobenzene	Liver, kidney	
Dichloromethane	Lung, liver	
1,4-Dioxane	Liver, nasal cavity	
Epichlorohydrin	Nasal cavity, forestomach	Respiratory tract
Ethylene dibromide	Forestomach, skin, lung	
Ethylene thiourea	Thyroid	
Hexachlorocyclohexanes	Liver	Leukemia
Hydrazine	Lung, liver, mammary glands, nasal cavity	
Lead compounds, inorganic	Kidney	
4,4'-Methylenebis (2-chloroaniline) (MOCA)	Lung, liver, mammary glands	Bladder
Polybrominated biphenyls (PBBs)	Liver	
2, 3, 7, 8-Tetrachlorodi-benzo-p-dioxin (TCDD)	Liver, lung, other	Soft tissue sarcoma and lymphoma
Tetrachloroethylene	Liver, leukemias	

*From IARC, 1987.

The U.S. National Institute for Occupational Safety and Health (NIOSH) calculated on the basis of the decennial National Occupational Exposure Survey that more than 7 million American workers have the potential for regular occupational exposure to proven human carcinogens. Firefighters are among these workers.

Investigators from the Mount Sinai School of Medicine have previously estimated that 10 per cent of all cancer deaths in New York State are due to occupational exposures. Work-related cancer among firefighters, however, is under-diagnosed. Many cancers that are work-related are mistakenly attributed to "lifestyle factors," old age, or to other poorly defined factors.

Several explanations exist for the under-diagnosis of occupational cancer among firefighters. These include:

- The long latency period (incubation period) that typically must elapse between exposure to a carcinogen in the workplace and the development of cancer.

- Simultaneous exposures of workers to multiple carcinogens. The simultaneous occurrence of multiple toxic exposures makes it difficult for epidemiologists and medical scientists to recognize the individual and combined effects of particular chemicals. This is a particular problem for firefighters who almost never experience exposure to single chemicals.

- Inadequate training. Most physicians are not adequately trained to suspect work as the cause of disease. Very little time is devoted in medical schools to teaching physicians to take a proper occupational history, to recognize the symptoms of exposure to common industrial toxins or to understand the associations between occupational exposures and disease.

- Inadequate carcinogenicity and toxicity testing. As noted above, only approximately 20% of industrial chemicals have been properly assessed for their carcinogenicity; therefore, it is nearly impossible for physicians to recognize as work-related cancers that occur in firefighters as a consequence of occupational exposure to the many thousands of untested chemicals.

B.3. TOXIC AND CARCINOGENIC EXPOSURES ENCOUNTERED BY FIREFIGHTERS.

Firefighters are exposed in their work to extremely high concentrations of a large number of toxic and carcinogenic chemical compounds. Some of these chemicals--for example, carbon monoxide and soot containing polycyclic aromatic hydrocarbons (PAH)--are natural products of combustion and have always been present at fires. They are commonly found in modern firefighting environments but were also encountered by firefighters 100 years ago. However, the combustion of modern synthetic and plastic materials produces many highly toxic and carcinogenic compounds that were not found in fires even three to four decades ago. These synthetic materials pose major hazards in present day fires.

Synthetic Chemicals. Since World War II, the production of synthetic chemicals has increased 350-fold. More than 70,000 distinct chemical substances are currently in commercial use in the United States and are registered with the U.S. Environmental Protection Agency. One thousand new compounds are added each year. The toxicity of only a minority of these chemicals has been tested. Fewer still have been subjected to combustion testing to determine which toxic compounds may be released from them in a fire environment.

In consequence of the proliferation of synthetic chemicals, firefighters are increasingly exposed to known and suspected carcinogenic agents whether at a fire in a residence, hardware store, drug store, dry cleaning establishment, pesticide warehouse or chemical manufacturing plant. The more than 30,000 existing hazardous waste sites and the transportation of hazardous substances pose still more new and significant potential health risks for firefighters.

Practically every emergency situation encountered occupationally by a firefighter has the potential for exposure to carcinogenic agents. Firefighters can also be exposed to carcinogenic agents when the protective clothing they wear is exposed to high heat or burns. Firefighters can be further exposed to carcinogens through the fire extinguishing agents they utilize (e.g. perfluorooctanoic acid contained in fire-extinguishing foam).

Patterns of Exposure. The potential of synthetic chemical substances to cause bodily harm to firefighters is dependent upon many factors at the fire scene: the concentration of exposure, duration of exposure, respiratory rate and volume, type of respiratory equipment used and clothing worn.

The exposure of firefighters to chemical carcinogens occurs most typically as the result of inhalation through the lungs, although some of these materials can penetrate the skin. Penetration of chemicals through the skin is enhanced when the skin is broken or abraded as frequently occurs during firefighting.

Firefighters have little information about the identity of many of the materials to which they are exposed or the potential hazards of such exposures. Nevertheless, firefighters continue to respond to the scene and work immediately to save lives and reduce property damage without regard to the potential hazards that may exist. Unlike any other work place, a fire emergency has no environmental controls or occupational safety and health standards to reduce the effect of toxic chemicals. It is an uncontrolled and uncontrollable environment.

Synergism. Firefighters are almost never exposed to one chemical compound alone. Instead, because of the proliferation of plastics and synthetics, they are exposed simultaneously to complex mixtures of multiple chemical compounds under conditions of great heat and stress. Multiple exposure is of great concern, because the health hazards of multiple carcinogenic exposures may be greater than the sum of the individual exposures. This interaction is termed synergism. Synergism among carcinogens poses a serious potential threat to firefighters.

In this section of the report, we summarize the principal toxic and carcinogenic hazards that are known to be encountered in modern firefighting. Obviously we cannot describe the hazards that may be posed by chemicals whose toxicity has not yet been tested. Nor do we speak further of synergism, about which little is known.

Chlorinated Hydrocarbons. Chlorinated hydrocarbons, used as solvents, degreasing agents, cutting fluids and fumigants, are commonly encountered at fires in dry cleaning establishments. Members of this family of chemicals include 1,2-dichloroethane (ethylene dichloride), found in fires at service stations, auto dealers and printers; 1,1,2trichloroethane (TCE), found in fires at retail stores, auto repair establishments, printers and dry cleaners; and 1,1,2,2,-tetrachloroethane (perchloroethylene). Recommendations that all three be treated as human carcinogens have been made by the National Institute for Occupational Safety and Health (NIOSH).

Another member of this group of organic chemicals are polychlorinated biphenyls (PCBs) which are heavy, oily liquids. Their chemical properties--high boiling point, chemical stability, low flammability, and heat resistance--make them ideal for use in many industries. Primarily, PCBs are found in electrical transformers and capacitors in utility companies, buildings, television sets, fluorescent lights and home air conditioners. They have also been used as heat transfer and hydraulic fluids; as dye carriers in carbonless copy paper; in paints, adhesives, and caulking compounds; and in sealants and road coverings that control dust. Additionally, they have been used in the manufacture of products including upholstering materials, washable wall coverings, paints and plastic bottles.

Although PCB production was banned by an Act of Congress in 1977, there are still millions of pounds remaining in active use in the United States today. PCBs are resistant to chemical and biological degradation; the only method for destruction is through high temperature incineration.

At high temperatures, under pyrolytic conditions, PCBs form at least two highly carcinogenic substances--polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzodifurans (PCDFs). PCDDs and PCDFs are also byproducts of pentachlorophenol, a commonly used wood preservative.

The exposure of firefighters to PCBs occurs in three ways: inhalation of air containing PCB vapors, mists or particulates; absorption or contact with the skin and eyes; and ingestion of contaminated food or other material. PCBs can readily penetrate the neoprene vapor barrier which is commonly used in protective clothing for firefighters. Once inside the body, they are circulated through the blood and stored in fatty tissues and other organs, especially the liver. In addition to cancers of the liver and pancreas, PCBs are associated with reproductive failure and nervous system damage.

Plastics and Their Combustion Products. Changes in the nature of firefighting during the last two decades have come about primarily because of the proliferation of plastic products. In the United States alone, it is estimated that over 30 billion pounds of plastics are produced annually. Firefighters can expect to encounter plastics at every fire to which they respond. Plastic products can be found in every home, office, store and vehicle.

Danger occurs when plastics are exposed to heat. As the material heats, decomposition begins. Toxic fumes and gases such as acid gas, aldehydes and cyanide are rapidly released. Because these fumes are either invisible or create only a thin fog-like haze, they appear to be harmless. In fact, these fumes are highly concentrated with toxic and carcinogenic gases that are potentially lethal. About 80% of all fire deaths occur because of the inhalation of these toxic fumes and smoke. When the combustion stage begins, the plastics break down even further releasing many other hazardous products.

Polyvinyl Chloride (PVC). The dominant plastic resin on the market, polyvinyl chloride, is formed from a monomer (vinyl chloride) that is a carcinogen known to cause cancer of the liver. PVC is used as a rubber substitute and as covering for electrical and telephone wires and cables. It can be found in plumbing pipe, molded furniture, electrical fixtures, upholstery, raincoats, house siding, shoe soles, disposable bottles, shower curtains, phonograph records, packaging equipment, automobile and aircraft seat covers, office equipment, baby pacifiers and other products too numerous to mention. Thus PVC can be assumed to be present at virtually every structural fire.

When PVC is heated to 480°F (250°C), decomposition occurs releasing clouds of hydrogen chloride and vinyl chloride monomer. During high temperature pyrolysis and combustion, PVC gives off a variety of chlorinated and nonchlorinated organic chemicals including benzene, toluene, formaldehyde, chloroform, chlorinated biphenyls, dioxins and dibenzofurans.

__Polyurethane and Polystyrene__. Urethane foams are found in mattresses, fold-out couches, upholstered furniture cushioning, thermal building insulation and car seat cushions. Hydrogen cyanide gas is released during decomposition and combustion, as well as carbon monoxide and organics such as benzene, acetaldehyde, and methanol. Polyurethane, almost as common as PVC, is used in flexible and rigid foams and found in automobiles. It contains small amounts of unreacted urethane which is offgassed during heating. Urethane is carcinogenic in laboratory animals and needs to be considered as if it were carcinogenic in humans.

Packing material, fast food wrapping, disposable drinking cups, and building insulation are among the uses of polystyrene. During combustion, it emits high concentrations of aromatic hydrocarbons; styrene, modified styrene, benzene, ethyl benzene; and phenols and phenyls.

Other plastics which release toxic and carcinogenic products during decomposition and combustion include acrylonitrile-butadiene-styrene (ABS) commonly found in luggage, plumbing pipe, and upholstery; teflon used in wire insulation, credit cards and cookware; and nylon found in carpets, upholstery and clothing. Clearly, firefighters have the potential for exposure to these compounds during fires in almost any setting.

__Benzene__. Benzene is found in gasoline, degreasing agents, model airplane and other glues, paint strippers, kerosene, rubber solvent, and many others products. Combustion of polyvinyl chloride, polyurethane, polystyrene, polyphenylene oxide, polyamide, polyolefin, and polyester plastics produces benzene. Firefighter exposure to benzene occurs during fires at gas stations, auto repair shops, printing shops and at homes containing furnishings made of synthetic materials. Because benzene is a product of the ubiquitous plastics that are routinely found in all homes, offices, and cars, it can be expected that firefighters are routinely exposed.

Benzene has been internationally recognized as a human carcinogen. Exposure and inhalation of benzene has been associated with leukemia and lymphoma.

__Pesticides__. Pesticides can be found in grocery stores, drug stores, plant shops, hardware stores, garden supply shops and residential homes. The list of carcinogenic pesticides includes chlordane, heptachlor, aldrin, dieldrin, mirex, chlordimeform and chloroform. Firefighters can encounter these compounds in a wide variety of fire settings.

__Polycyclic Aromatic Hydrocarbons (PAH)__. Firefighters are consistently exposed to various soots and tars that have been shown to cause cancers of the skin, lung and bladder. Polycyclic aromatic hydrocarbons (PAH) are formed during combustion of organic materials such as fossil fuels and are thus present at every fire. PAHs are an active carcinogenic agent in soot.

PAHs are associated with increased incidence of bladder cancer, lung cancer and skin cancer and may contribute to excesses of these cancers observed in firefighters.

Flame Retardants. Firefighter exposure to carcinogens occurs through the use of protective clothing and devices. Asbestos has been used in firefighting clothing and fire blankets. Carbon tetrachloride was used in fire extinguishers for electrical fires and is still used as a metal degreaser, refrigerant and grain fumigant. A known animal carcinogen, carbon tetrachloride has been reported to cause liver cancer in humans. MOCA (4,4-methylene bis [2-chloroaniline]), once found as insulation in firefighter helmets and boots, is also used in the manufacture of isocyanate resins used in the plastics, aircraft, resin and synthetic rubber industries; in radio and television equipment; and in space and missile components. It too is a probable human carcinogen.

Formaldehyde. Formaldehyde is an irritating, toxic and carcinogenic gas that is formed in the combustion of natural organic materials and plastics. It is produced at every structural fire where wall papers or lacquered wall coverings burn. Formaldehyde has been shown in carefully conducted epidemiologic studies to be capable of causing cancer of the lung and nasal sinuses.

Asbestos. Asbestos has been the dominant material used for thermal insulation for the past five decades. It is ubiquitous and can be expected to become airborne during fires, especially during the overhaul stage. Asbestos is a well established human carcinogen to a variety of organs.

Summary. Firefighters experience uniquely intense occupational exposures to a wide range of known carcinogens. Additionally, they are exposed in their work to an unknown number of potential carcinogenic chemical compounds whose cancer-causing capacity has never been evaluated. Firefighters are seldom exposed to a single toxic chemical alone. Instead, they are exposed to complex mixtures of multiple toxins and carcinogens.

C. RISK OF CANCER IN FIREFIGHTERS

C.1. EPIDEMIOLOGIC STUDIES OF CANCER IN FIREFIGHTERS.

Cancer among firefighters has been studied extensively. A substantial body of epidemiologic literature now exists on the carcinogenic hazards of firefighting, and the number of studies is growing. Three new studies have been released in the first quarter of 1994 and are included in this report.

Leukemia, lymphoma, multiple myeloma, melanoma, and cancer of the lung, urinary tract, stomach, colon, rectum, prostate and brain are malignancies that have been observed with increased frequency among firefighters. Each of these cancers can be linked plausibly with specific toxic and carcinogenic chemical exposures to which firefighters are exposed in the course of their work.

The full extent of the occupational cancer risk of firefighters is not yet known. It is likely that in the years ahead, additional cancers will be found to be causally associated with exposures encountered by firefighters and that additional chemicals to which firefighters are already known to be exposed will be found to be carcinogenic. Nevertheless, despite the gaps in scientific knowledge, it is clear that firefighting causes a substantial risk of occupational cancer.

This chapter summarizes the epidemiologic literature on cancer among firefighters. It is important to acknowledge that none of the studies described here is perfect. Most of the studies examined relatively small populations of firefighters and thus have low statistical power to analyze rare tumors. To increase sample size, many of the studies analyzed deaths occurring over several decades; this technique introduces problems related to (a) trends in diagnoses, (b) differences in exposure over time, since many potential carcinogens (chemicals and synthetic materials) were introduced at different times during the relevant exposure periods, and (c) changes in protective equipment and awareness of hazards. Limited documentation of exposure is also a problem. Some studies relied on occupation as recorded on a death certificate or tumer registry, which may reflect the current or most recent job, not the usual occupation.. Recent studies have examined risk in relation to duration of active fire combat duty, latency (years since hire) and age at diagnosis (estimating active duty versus retirement). However, none were able to rank firefighters according to a cumulative index of intensity of exposure. As a result, heavily exposed firefighters are co-mingled with lightly exposed firefighters, and the risks to the heavily exposed firefighters are diluted out and under-estimated by the design of the studies. Another shortcoming is the lack of data on confounders that are known risk factors for cancer, e.g., cigarette smoking and alcohol consumption. Finally, the majority of studies have been conducted in cities and states that differ greatly from New York, with lower population and building density and older, low-rise structures. In consequence, the firefighters examined in those studies have not experienced the intensity or the number of hazardous exposures that are encountered daily by firefighters in New York.

The shortcomings of these studies are much more likely to dilute or mask associations between occupational exposures and cancer than to create falsely positive associations. The results of the studies are also subject to the paradox of the ***healthy worker effect***. Healthy individuals are more likely than unhealthy persons to seek and gain employment, and to remain in their jobs. This effect is amplified by the stringent initial screening process for employment as a firefighter, as evidenced by their low all-cause mortality rates. Therefore, higher than expected rates of cancer mortality among firefighters, in comparison to the general population as well as other groups of workers, are unsettling. The studies are undoubtedly under-estimating the full extent and magnitude of the occupational cancer risk of firefighters. The fact that increased rates of cancer have been found consistently is evidence of the severity of the hazards and a reflection of the high risk of cancer that confronts firefighters.

Despite the limitations cited above, the available epidemiologic and medical literature presents convincing and consistent evidence of causal associations between toxic exposures encountered in firefighting and cancer. In the mid-1970's, the situation was similar for cardiovascular disease, the first major chronic health effect of firefighting to be evaluated using epidemiologic methods. The consensus of experts who reviewed those data was that the criteria for a causal association with firefighting were met.

The eighteen studies on cancer in firefighters published in the medical literature are summarized below, in chronological order. Graphic presentations of the results by cancer type are shown in Section D. of this report.

[*N.B.* The following measures are used in these studies to express the magnitude of the observed associations between firefighting and cancer:

a. <u>Standardized Mortality Ratio (SMR)</u>. An SMR greater than 100 indicates that the observed number of deaths from a specific cancer observed in the firefighters is <u>greater</u> than the expected number of deaths (observed # / expected # x 100).

b. <u>Proportionate Mortality Ratio (PMR)</u>. A PMR greater than 100 indicates that the observed proportion of all deaths among the firefighters that were due to a specific cancer is <u>greater</u> than the expected proportion (observed proportion / expected proportion x 100).

c. <u>Relative Risk (RRx100) or Incidence Density Ratio (IDRx100)</u>. A value greater than 100 indicates that the mortality rate or incidence rate for a specific cancer in firefighters is <u>greater</u> than the death rate or incidence rate in an unexposed population (rate in exposed / rate in unexposed x 100)

d. "<u>Statistical significance</u>" indicates that the likelihood is less than 5 percent that the observed association between firefighting and cancer occurred simply by chance. Significance is determined by the magnitude of the exposure-disease association, the size of study population and the accuracy or variability of the exposure and disease measurements.]

1. **Mastromatteo (1959): Mortality in city firemen.**

This study compared cause of death as coded on death certificates (N=271) among firefighters in Toronto, Ontario, Canada who were active between 1921 and 1953 to population death rates during the same period.

Although firefighters showed a significant excess of deaths overall and from cardiovascular and renal disease in particular, the observed number of deaths from cancer equalled the expected number. This early study is historically important, since the period of active duty for all these firefighters clearly preceded the widespread use of synthetic materials and many carcinogenic chemicals.

2. **Musk et al. (1978): Mortality among Boston firefighters, 1915-1975.**

Causes of death from death certificates (N=2,470) for 5,655 male firefighters employed in Boston at least three years between 1915 and 1975 were compared to rates from Massachusetts and from the United States. This study found no increase in overall cancer deaths, but excess mortality from **cancer of the rectum** (SMR=153).

3. **Dubrow and Wegman (1983): Setting priorities for occupational cancer research and control: Synthesis of the results of occupational disease surveillance studies.**

These authors reported in the Journal of the National Cancer Institute the combined results from 12 large occupational disease surveillance studies. Their goals were to identify occupations with particularly high cancer risk and to make recommendations concerning priorities for cancer research and prevention. The strongest, most consistent occupation-cancer associations in the literature were tabulated. The occupational group "firemen and fire protection" was strongly associated with **cancer of the colon** (aggregate SMR=128) and **multiple myeloma** (aggregate SMR=204).

4. **Eliopulos et al. (1984): Mortality of fire fighters in Western Australia.**

This study followed 990 male firefighters employed by the Western Australia Fire Brigade between 1939 and 1978. Death certificates were obtained for 116 who died by end of 1978, and proportional mortality (PMR) analysis was conducted relative to the general population.

The authors state that cancer was the only cause of death that stood out among generally low rates of death among firefighters: the excess of number of cancer deaths (PMR=152) approached statistical significance when respiratory cancers were excluded. The proportion of deaths was higher than expected for **cancer of the**

stomach (PMR=202), **large intestine** (PMR=159), **lymphatic and hematopoietic systems** (PMR=188) and for "other cancers" (PMR=297) of which 3 out of the 4 were **brain tumors**. There was no trend of increasing risk with increasing duration of employment or latency (time since hire).

5. **Feuer and Rosenman (1986): Mortality in police and firefighters in New Jersey.**

The Police and Firemen Retirement System records in New Jersey listed 901 deaths occurring between 1974 and 1980. Age-adjusted PMRs for firefighters and police were calculated in reference to the general population of New Jersey and the US.

Statistically significant PMRs among firefighters were found for **skin cancer** (PMR=270 compared to US population) and **leukemia** (PMR=276 compared to police). Excess skin cancer and leukemia was consistently evident relative to the police, the population of New Jersey or the US population. Skin cancer risk increased with duration of employment and latency.

6. **Vena and Fiedler (1987): Mortality of a municipal-worker cohort: IV. Fire fighters.**

The mortality experience of 1,867 firefighters who worked full-time at least one year between 1950 and 1979 in Buffalo, NY was compared to the mortality experience of the US white male population. Mortality according to length of employment (1-9, 10-19, 20-29, 30-39, 40+ years) was presented for 470 observed deaths among the firefighters.

Overall cancer mortality was highest in long-term firefighters, and risk increased with increasing latency (SMR=220 for all malignant neoplasms after 40 years). Statistically significant SMRs, particularly among firefighters employed 40 years or more, were seen for **cancer of the colon** (overall SMR=183, 40+ years SMR=471) and **bladder** (overall SMR=284, 40+ years SMR=571). Elevated SMRs for cancer of the **rectum** (SMR=208), **esophagus** (SMR=134) and **kidney** (SMR=130) were not statistically significant. For firefighters employed 20-29 years, a statistically significant elevated SMR of 375 was found for **brain cancer** (overall SMR=236). The risk of brain cancer was particularly high for firefighters hired after 1940,

7. **Hansen (1990): A cohort study on the mortality of firefighters.**

Mortality in a cohort of 886 Danish male firefighters employed in 1970 was determined for a five-year period (1975-1980) and compared to a cohort of unexposed workers.

Among the 36 deaths that occurred by non-accidental causes, the excess number of cancers among firefighters was statistically significant (SMR=173). An excess of **lung cancer** deaths (SMR=220) was observed; the excess was statistically significant in those age 60 to 74 (SMR=317). All "other cancers" combined resulted in significantly elevated risk among men age 30-49 (SMR=575); these were comprised of four **digestive system cancers** (one stomach, two rectal and one pancreatic cancer) and one unspecified cancer.

8. Heyer et al. (1990): Cohort mortality study of Seattle fire fighters: 1945-1983.

A cohort of 2,289 male firefighters employed by Seattle Fire Department for at least one year between 1945 and 1980 was followed. Death certificates were obtained for 383 who died as of 1983. Exposure was defined as time spent in active fire combat duty, exclusive of administrative duty.

Overall, elevated SMRs were observed for **brain cancer** (SMR=218) particularly within 15 years of hire; **leukemia** (SMR=173); and **multiple myeloma** (SMR=225). However, the only statistically significant results were seen among firefighters with 30 years or more combat duty for leukemia (SMR=503) and multiple myeloma (SMR=989), and among firefighters age 65 years or more for **lung cancer** (SMR=177).

9. Demers et al. (1992): Mortality among firefighters from three northwestern United States cities.

Expanding on the preceding study by Heyer et al., the authors assessed mortality in 4,546 firefighters employed for at least one year between 1944 and 1979 in Seattle and Tacoma, WA and Portland, OR. Death certificates were obtained for 1,162 firefighters who died by 1989; SMRs for specific cancers were computed using death rates from white males in the US and from a cohort of police from the same cities. Years of active fire combat duty was used as a surrogate measure of exposure.

A statistically significant excess of **brain cancer** (SMR=209), as well as non-significant excesses of **lymphatic/hematopoietic cancers** (SMR=131) and **prostate cancer** (SMR=134), were found compared to the US population. Brain cancer was also more common among firefighters than police (SMR=188). Younger firefighters (less than 40 years of age) had significantly increased risk of brain cancer (SMR=375) and increased lymphatic/hematopoietic cancers (SMR=174), as did those with less than 20 years from hire (SMRs=245 and 165, respectively). The rates for brain and lymphatic/hematopoietic cancers were also high in those age 65 and older (SMRs=234 and 161, respectively) and significantly elevated in those 30 years or more from hire (SMRs=263 and 148, respectively). **Leukemia** was in excess among firefighters age 65 and older (SMR=167).

10. Demers et al. (1994): Cancer incidence among firefighters in Seattle and Tacoma, Washington (United States).

The authors of the two preceding reports studied incident cases from cancer registries, rather than only death certificates, from Seattle and Tacoma, WA. A total of 2,447 male firefighters who were employed at least one year between 1944 and 1979 were followed for 16 years (1974-89); 242 incident cancers were identified. Standardized incidence ratios (SIR, similar to SMR) relative to the general population and incidence density ratios (IDR, similar to relative risk x 100) relative to police were calculated.

Compared to the general population, the risk of **prostate cancer** was significantly elevated (SIR=140); moderate nonsignificant excesses were seen for **stomach cancer** and **melanoma of the eye**. Compared to police, the risk of **non-Hodgkin's lymphoma** (IDR=180) and **cancers of the bladder** (IDR=170), **brain** (IDR=140), **colon** (IDR=130) and **rectum** (IDR=130) were somewhat elevated. Only the risk of colon cancer appeared to increase with increasing duration of employment. The risk of all cancers combined was similar for firefighters, police and the general population in all analyses (overall, by latency, or by duration of exposure).

11. Howe and Burch (1990): Fire fighters and risk of cancer: An assessment and overview of the epidemiologic evidence.

These authors combined the results of all cancer mortality studies of firefighters available as of 1990. They derived pooled estimates of risk for specific types of cancer and strictly evaluated the consistency of the results of the various studies. For three cancers, there was evidence of a consistent association with firefighting: **brain cancer** (SMR=145), **multiple myeloma** (SMR=151) and **melanoma** (SMR=173).

12. Sama et al. (1990): Cancer incidence among Massachusetts firefighters: 1982-1986.

Using the Massachusetts Cancer Registry, all cancer cases diagnosed from 1982-1986 in males were identified. Three groups of registry cases were considered: exposed firefighters (315 white males with usual occupation of firefighter or fire chief); unexposed police; unexposed state residents with any occupation other than firefighter or chief. Age-adjusted standardized mortality odds ratios (SMOR) compared the observed odds of cancer in exposed group to expected odds from each of the two comparison groups.

Compared to the state reference group, statistically significant SMORs were observed for **melanoma of the skin** (SMOR=292) and **bladder cancer** (SMOR=159); **non-Hodgkin's lymphoma** was elevated but not statistically significant (SMOR=159). Compared to the police, statistically significant results were seen for bladder cancer (SMOR=211) and non-Hodgkin's lymphoma (SMOR=327);

elevated nonsignificant results were seen for **pancreatic cancer** (SMOR=319), **leukemia** (SMOR=267) and **brain cancer** (SMOR=152).

13. Beaumont et al. (1991): An epidemiologic study of cancer and other causes of mortality in San Francisco firefighters.

Age-standardized mortality rates for 3,066 white male San Francisco firefighters employed for at least three years between 1940 and 1970 were determined. Deaths that occurred through 1982 were examined in comparison to expected numbers and rates of death from the US population.

A statistically significant excess was seen for **cancer of the esophagus** (RRx100=204); among subgroups by years since hire, **stomach cancer** was significantly increased after 40+ years (RRx100=232) and **biliary tract (includes liver or gall bladder) cancer** after 30-39 years (SMR=387). Death rates for cancer of the **lip, rectum and skin** were also higher than expected overall, but not statistically significant.

14. Giles et al. (1993): Cancer incidence in Melbourne metropolitan fire brigade members, 1980-1989.

This study followed a cohort of 2,865 white male firefighters employed in Melbourne, Australia between 1917 and 1989. Record linkage to the Victorian Cancer Registry identified 50 firefighters diagnosed with cancer between 1980 and 1989. The observed number of cases was compared to the expected number based on the general population rates.

Although none of the increases were statistically significant, standardized incidence ratios (SIR, similar to SMR) were elevated for **cancer of the prostate** (SIR=209), **upper digestive tract** (SIR=146) and **colon and rectum** (SIR=136), and for **non-Hodgkin's lymphoma** (SIR=185). For men age 65 and over, the SIRs for **all cancers** combined (214) and for colorectal cancer (365) were statistically significant. Analyses by duration of employment and latency yielded no significant results.

15. Guidotti et al. (1993): Mortality of urban firefighters in Alberta: 1927-1987.

A cohort of 3,328 firefighters active from 1927 to 1987 in Edmonton and Calgary in Alberta, Canada was studied; death certificates for 370 deaths occurring by 1987 were obtained. Observed number of deaths was compared to expected numbers based on rates for male residents of Alberta. This study attempted to quantify degree of exposure to the hazards associated with firefighting; years of active service were weighted by an "exposure opportunity index" based on job classification, with a maximum weight of 1.0 used for time spent as an active paid firefighter, lieutenant or captain.

Overall, statistically significant excesses were found for **all cancer** (SMR=127) and **cancer of the kidney or ureter** (SMR=414). Other sites of increased risk included **cancer of the bladder** (SMR=316), **colon and rectum** (SMR=161), **pancreas** (SMR=155), **brain** (SMR=147), **prostate** (SMR=146) and **lung** (SMR=142), and of **leukemia, lymphoma and multiple myeloma** combined (SMR=127). An association with **genitourinary tract cancers** is most consistent with these data, and the effect was strongest in those with long duration of employment and greatest exposure opportunity. There were no other consistent associations with duration of employment, exposure opportunity or entry before or after 1950.

16. Tornling et al. (1994): Mortality and cancer incidence in Stockholm fire fighters.

This study investigated 1,116 men who worked at least one year as firefighters in the City of Stockholm, Sweden between 1931 and 1983. Record linkage was used to determine vital status, cancer diagnosis and cause of death (N=316) through 1986. An individual exposure index was calculated from the number of fires fought each year at each fire station, and the number of fires at which the firefighter used a self-contained breathing apparatus (SCBA). SMRs were calculated relative to regional population cancer incidence and mortality rates.

The total cancer incidence and mortality were at the expected level, however, increasing risk was observed with increasing age, employment time and number of fires. Incidence of **stomach cancer** was significantly more common than expected (incidence SMR=192, mortality SMR=121); both incidence and mortality increased with duration of employment and number of fires. Excess mortality from **brain cancer** was seen (incidence SMR=137, mortality SMR=279) with increasing risk with increasing exposure, i.e., age 65+ years, employed for 20+ years, and after 30+ years of latency. Incidence was nonsignificantly elevated for **cancer of the rectum and anus** (SMR=170) and for **skin cancer** (SMR=151) excluding melanoma (SMR=79). Mortality was nonsignificantly elevated for **cancer of the rectum and anus** (SMR=207), **liver** (SMR=149) and **prostate** (SMR=121).

17. Burnett et al. (1994): Mortality among fire fighters: A 27 state survey.

This latest study examined the mortality experience of firefighters from 27 states representing wide geographic coverage of the US; the data include deaths from all of New York State except New York City. The cause of death was determined for 5,744 white male firefighters who died during the period 1984-1990.

Age-adjusted proportionate mortality ratios (PMR) for specific causes, compared to deaths from all causes, were computed separately for deaths occurring before age 65 (similar to active duty) and for all ages (active duty plus retired).

Elevated PMRs (statistically significant for either age category) were found for:

	Under age 65	All ages
All cancer	112	110
Rectum	186	148
Skin	167	163
Kidney	141	144
Lymphatic/ Hematopoietic:	161	130
Non-Hodgkin's lymphoma	161	132
Multiple Myeloma	136	148
Leukemia	171	119

Strengths of this study include its size (the number of deaths analyzed is much larger than in most studies), recency of the mortality period and broad geographic representation of firefighters in the US.

18. Liou et al. (1989): Biological monitoring of fire fighters: Sister chromatid exchange and polycyclic aromatic hydrocarbon-DNA adducts in peripheral blood cells.

The techniques of molecular biology are being used increasingly to develop biomarkers of exposure in occupational and environmental settings. This study monitored two biomarkers in firefighters: sister chromatid exchange (SCE), a general indicator of genetic damage resulting from exposure to mutagens and carcinogens, and polycyclic aromatic hydrocarbons (PAH)-DNA adducts, which are thought to measure the initiation of carcinogenic changes associated with exposure to polycyclic aromatic hydrocarbons. Increased levels of PAH-DNA adducts among workers exposed to combustion products and among cigarette smokers have been reported.

Blood was obtained from 43 active firefighters in Washington, DC and from a group of unexposed controls. These firefighters, on average, had a relatively low level of firefighting activity; 40 percent were not involved in fire combat activity in the week before blood collection. Nevertheless, after controlling for charcoal-broiled food consumption, cigarette smoking and race, white firefighters had a statistically significant four-fold higher risk of detectable PAH-DNA adduct levels compared to controls. (The number of non-white firefighters was too small for adequate analysis.)

This association may be specific to urban, structural firefighting, as a similar study in wildland firefighters in California found no association between forest fire activity and PAH-DNA adducts.

C.2. PREVALENT CANCERS IN FIREFIGHTERS AND THEIR ASSOCIATIONS WITH CARCINOGENIC OCCUPATIONAL EXPOSURES.

Cancer among firefighters has been the subject of intense medical and epidemiologic research. This research has been prompted by the recognition that firefighters are exposed in their work to high doses of multiple chemical carcinogens, as discussed in Section B. To date, eighteen epidemiologic studies of cancer in firefighters have been published in the medical literature and these are summarized above. Graphic presentations of the results for each cancer, found in Section D., illustrate the preponderance of evidence implicating the carcinogenic hazards of firefighting. The strongest evidence that firefighters are at increased risk of developing and dying from several specific cancers is provided by the following studies (first author indicated):

Cancers of the lymphatic and hematopoietic systems, including leukemia, non-Hodgkin's lymphoma and multiple myeloma (Eliopulos, Dubrow, Feuer, Sama, Howe, Demers 1992 and 1994, Giles, Guidotti, Burnett)

Digestive tract cancers, including esophagus, stomach, colon, rectum, liver and biliary tract, pancreas (Hansen, Dubrow, Eliopulos, Vena, Sama, Beaumont, Giles, Guidotti, Tornling, Demers 1994, Burnett)

Urinary tract cancers, including the kidney, ureter and bladder (Vena, Sama, Giles, Guidotti, Demers 1994, Burnett)

Prostate cancer (Lewis, Guidotti, Tornling, Demers 1994)

Skin cancer, both melanoma and non-melanoma (Feuer, Howe, Sama, Beaumont, Tornling, Burnett)

Brain (central nervous system) cancer (Lewis, Eliopulos, Vena, Sama, Heyer, Howe, Demers 1992 and 1994, Guidotti, Tornling)

Each of these particular cancers can be plausibly linked biologically with carcinogenic chemical exposures encountered by firefighters in their work. In this section, we summarize the occupational and environmental exposures known to be associated with these cancers. It is unlikely that the associations observed between these exposures and these cancers can be attributed solely to the personal lifestyle factors (diet, cigarette smoking, alcohol intake) or medical treatments (radiation or chemotherapy) that have been linked with certain cancers; therefore, these factors will not be discussed further.

As discussed in Section B., the fire environment encountered by New York City firefighters is especially hazardous. Fires fought from the interior of burning structures are notable, since the synthetic materials used in the construction and furnishings of newer buildings release myriad potentially carcinogenic products of combustion. These materials are used in plastic plumbing pipes and as insulation for electrical equipment, wiring and cables, thus, they are found in the majority of structures. However, they are highly concentrated at certain sites, for example, the facilities of telephone companies or power utilities. In addition, fires in the many warehouses and businesses that utilize and store chemicals, solvents and paints, and in automobiles containing increasing amounts of synthetic materials, pose further risks for New York City firefighters.

a. <u>Cancers of Lymphatic and Hematopoietic Systems</u>.

Leukemia is a malignant disease of the blood-forming organs, characterized by distorted proliferation and development of white blood cells in the blood and bone marrow, which affects adults of all ages. Leukemia has been shown to be caused by occupational exposure to benzene and 1,3-butadiene. Benzene is a solvent in common use, a component of gasoline, and a combustion product that arises in the burning of plastics and synthetics. 1,3-butadiene is a monomer found in tires and synthetic rubber products. New York City firefighters are regularly exposed to the gases released by these materials as they burn.

Non-Hodgkin's Lymphoma includes several malignant diseases arising from the lymphoid components of the immune system. Environmental risk factors include exposure to dioxin, benzene and 1,3-butadiene. All of these are carcinogens to which firefighters in New York City are frequently exposed.

Multiple Myeloma is a malignant proliferation of plasma cells from the bone marrow. Chemical exposures that have been associated with multiple myeloma include benzene and petroleum products. New York City firefighters are likely to encounter these chemicals whenever there are plastics and other synthetic materials at a fire. Multiple myeloma is increased in farmers, paper producers, furniture manufacturers, wood workers and firefighters.

b. <u>Cancers of Digestive System</u>.

There are several established occupational exposures that increase the risk of cancer at these sites. It is hypothesized that, once cleared from the airways, inhaled particles and the carcinogens that adhere to them are transferred to the gastrointestinal tract and swallowed. They then exert their effect on the digestive epithelium.

Colon and Rectum Cancers are associated with dietary and genetic factors. In addition, workers with exposure to asbestos--including firefighters--have higher than expected rates.

Primary **Liver Cancer** is rare in the general US population. Angiosarcoma of the liver has been consistently associated with occupational and environmental exposures including arsenic and vinyl chloride monomer (from PVC). PVC can be assumed to be present at every structural fire site involving furniture, electrical wire and cable insulation and water pipes, as well as at automobile fires.

Cancer of the Pancreas is diagnosed in 28,000 persons in the US annually and the incidence is increasing. There is evidence that exposure to benzidine, ß-naphthylamine derivatives, and metal dusts increase the risk of pancreatic cancer. Firefighter exposure can occur during fires at printing shops or when tires or other rubber products burn.

Adenocarcinoma of the Stomach and **Cancer of the Esophagus** have been associated with asbestos exposure; as discussed above, asbestos is prevalent at the majority of structural fires fought in New York City.

c. **Cancers of Genitourinary System.**

Bladder Cancer. Occupational chemical exposures known to cause bladder cancer include several aromatic amines, solvents, benzidine, PAH, coal tars and pitches, soot and oils. These are common exposures encountered by firefighters at fires at many commercial establishments including printers, dry cleaners and service stations.

Kidney Cancer (renal cell carcinoma) has increased in incidence over the past decade. Environmental exposures that have been implicated include asbestos, PAH, lead phosphate, dimethyl nitrosamine, coke oven emissions and gasoline.

Prostate Cancer. High rates of prostate cancer have been reported among workers with cadmium exposure, and in firefighters, chemists, farmers, loggers, textile workers, painters and rubber tire workers.

d. **Skin Cancer** is a heterogeneous group of diseases, the majority of which are malignant melanoma (30,000 new cases in the US per year) or basal cell or squamous cell carcinomas (500,000 new cases in the per year). The most common risk factor is prolonged and intense sunlight exposure. Occupational exposure to soot and tars has been related to excess risk of skin cancer, particularly malignant melanoma; this may explain the strong association with firefighting. Arsenic, cutting oils and coke oven emissions have also been associated with increased risk.

e. <u>Brain (central nervous system) Cancer</u>. Chemical exposures that have been linked to brain tumors include vinyl chloride, benzene, PAH, N-nitroso compounds, triazenes and hydrazines. Brain cancer has been consistently and strongly associated with firefighting in recent studies, generally among younger firefighters and within 15-30 years of exposure, i.e., after a relatively short latency period.

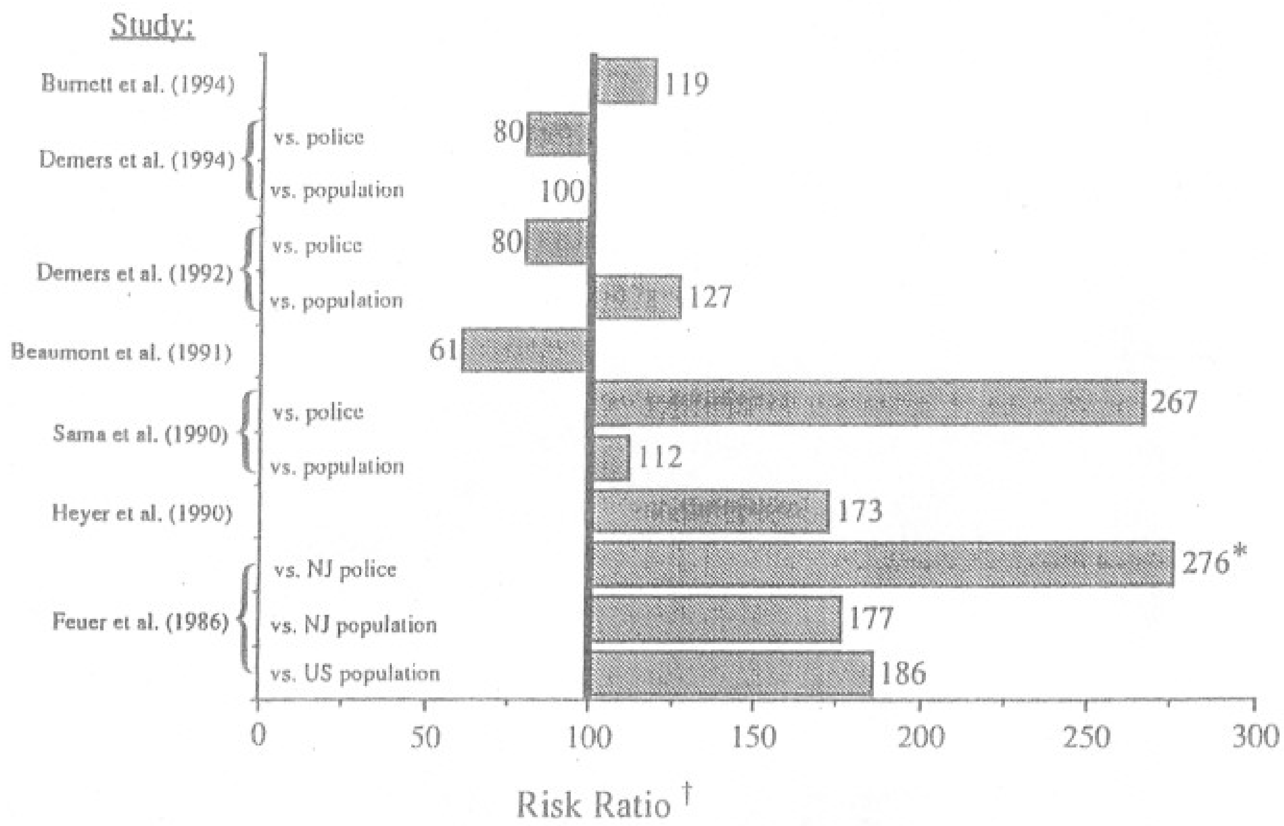
D. GRAPHS SUMMARIZING STUDIES OF CANCER IN FIREFIGHTERS.

Each graph in this section lists the results from all of the studies of firefighters that reported on that specific cancer. For a given study, the "Risk Ratio" reported is the measure the authors used to express the association between firefighting and cancer (definitions of the measures appear on page 16): either a standardized mortality ratio (SMR), proportionate mortality ratio (PMR), relative risk (RR multiplied by 100) or incidence density ratio (IDR multiplied by 100).

The range of values for the Risk Ratio is from 0 up to infinity. The null value is 100, indicating no excess cancer risk in firefighters. Values greater than 100 indicate the excess cancer risk associated with firefighting. For example, a Risk Ratio of 200 means that firefighters had twice the risk (a 100 percent increase) compared to the reference population; a value of 50 means that firefighters had half the risk (a 50 percent decrease) compared to the reference population.

Unless otherwise stated, the reference group used to calculate a Risk Ratio was the general or US population; certain studies calculated Risk Ratios for more than one reference group, for example, the police and the general population.

LEUKEMIA AMONG FIREFIGHTERS

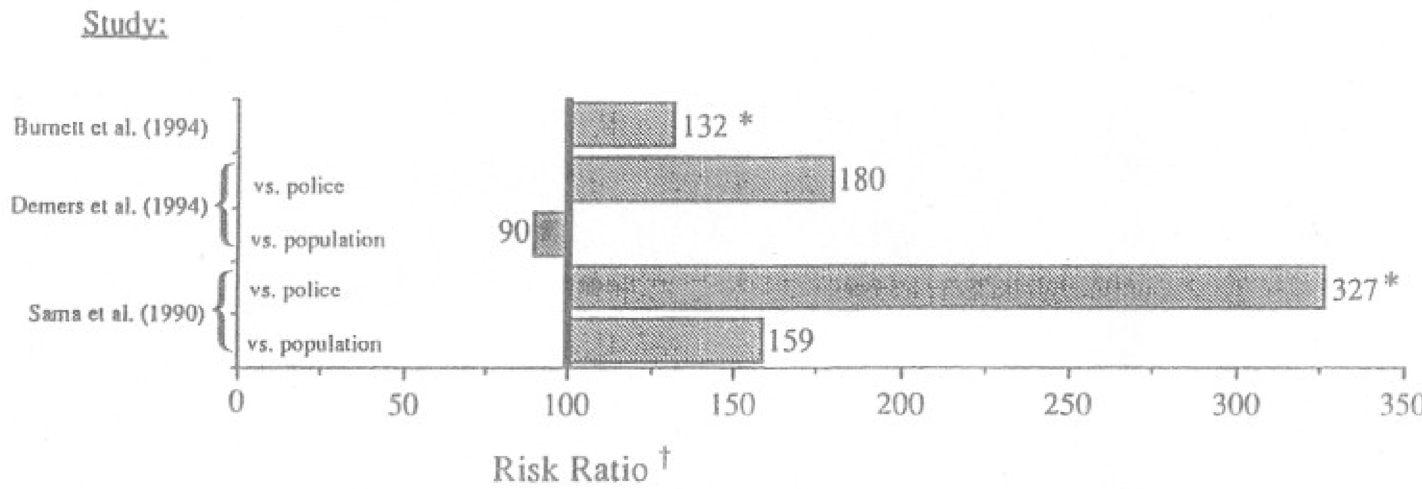


† Risk Ratio: SMR, PMR, or RR. Null value (no excess risk) equals 100.

*Statistically significant increase in risk.

This graph demonstrates that, in the majority of studies, firefighters clearly have excess risk of leukemia - almost 3 times the risk of police officers in some reports.

NON-HODGKIN'S LYMPHOMA AMONG FIREFIGHTERS

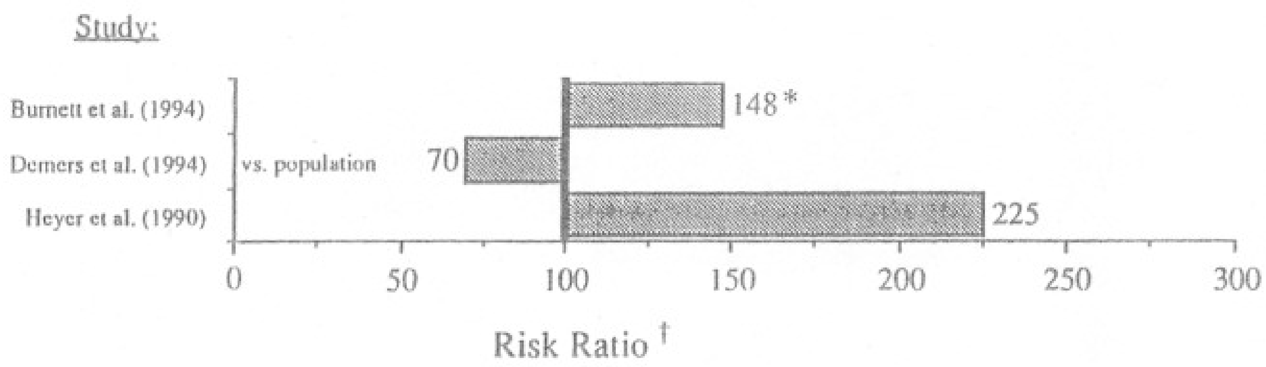


† Risk Ratio: SMR, PMR, or RR. Null value (no excess risk) equals 100.

*Statistically significant increase in risk.

All of the studies that looked at **lymphoma** found excess risk among firefighters, in comparison to police or the general population. The association with firefighting is strong and statistically significant in 2 of the studies.

MULTIPLE MYELOMA AMONG FIREFIGHTERS

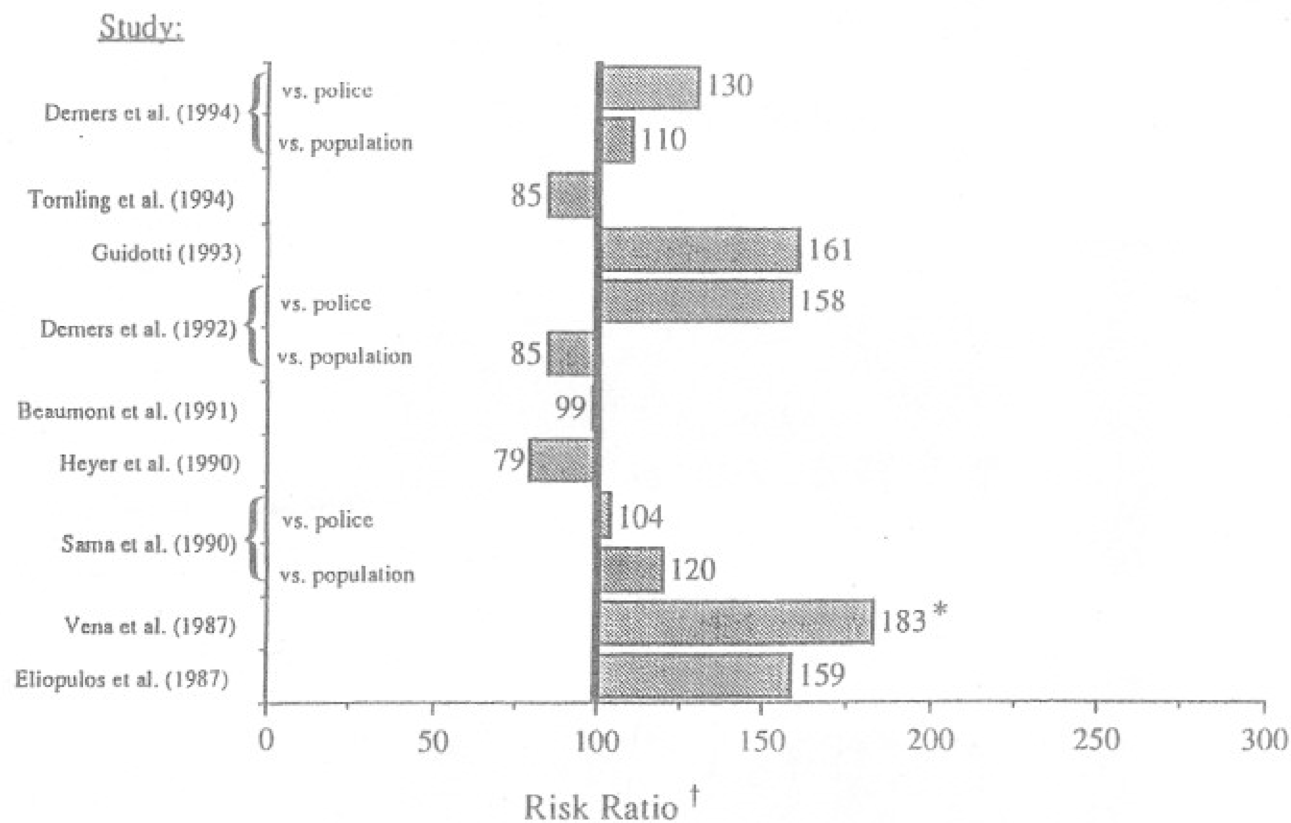


†Risk Ratio: SMR, PMR, or RR. Null value (no excess risk) equals 100.

*Statistically significant increase in risk.

Multiple myeloma was strongly associated with firefighting in 2 of these 3 studies. An analysis that combined the results of all the available studies (Howe and Burch) determined that multiple myeloma was one of the 3 cancers most consistently associated with firefighting.

COLON CANCER AMONG FIREFIGHTERS

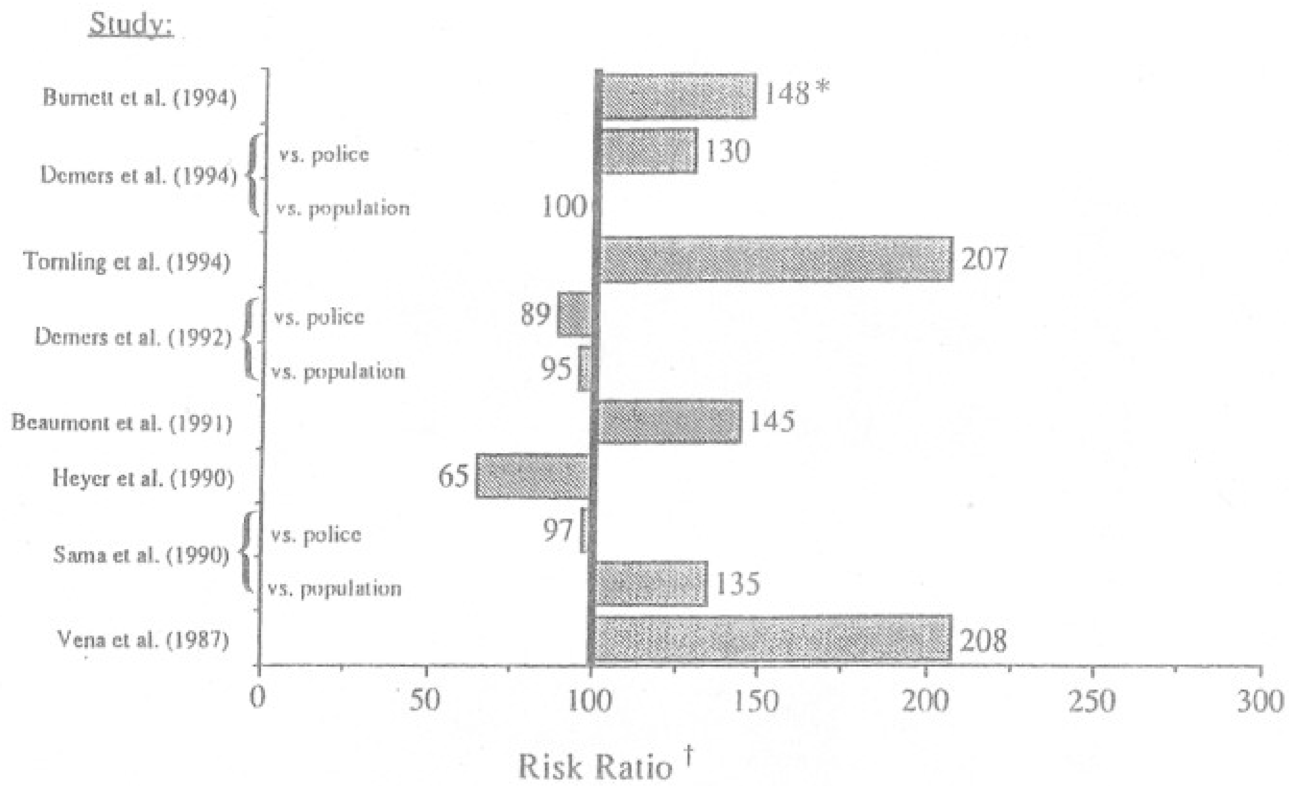


†Risk Ratio: SMR, PMR, or RR. Null value (no excess risk) equals 100.

*Statistically significant increase in risk.

Many studies looked at **colon cancer** and this graph demonstrates the consistent moderate to high excess risk found for firefighters.

RECTAL CANCER AMONG FIREFIGHTERS



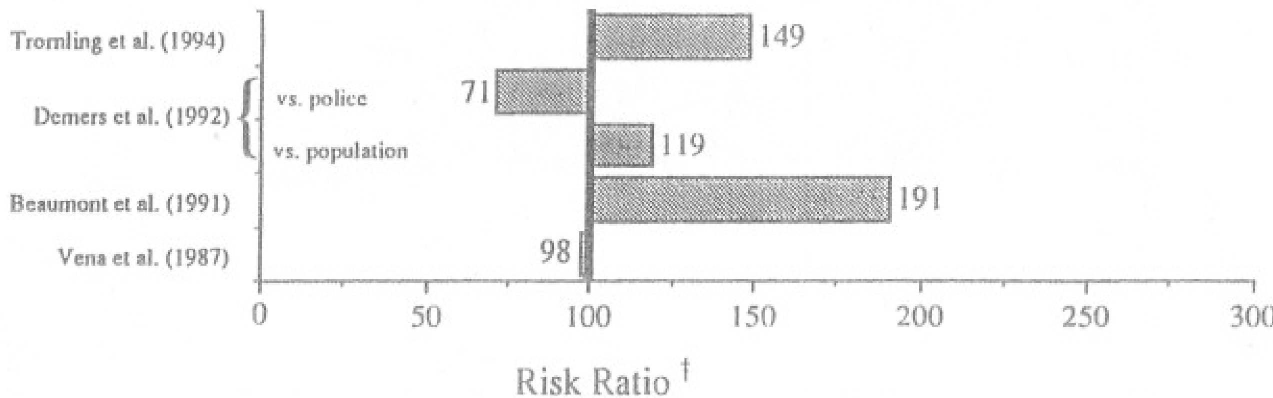
†Risk Ratio: SMR, PMR, or RR. Null value (no excess risk) equals 100.

*Statistically significant increase in risk.

These studies show that the risk of cancer of the rectum among firefighters appears to be even higher than the risk of colon cancer.

LIVER CANCER AMONG FIREFIGHTERS

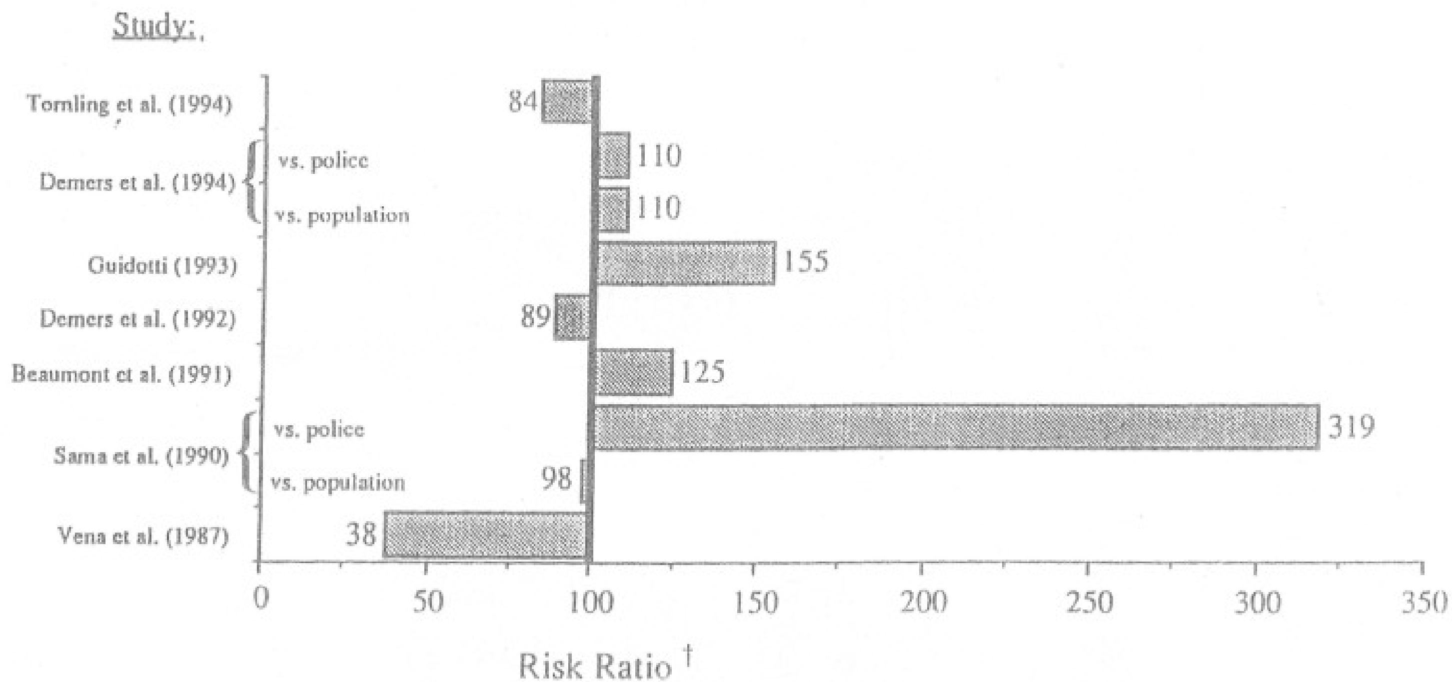
Study:



† Risk Ratio: SMR, PMR, or RR. Null value (no excess risk) equals 100.

This graph indicates that in most studies, the risk of liver cancer was higher for firefighters than for the general population.

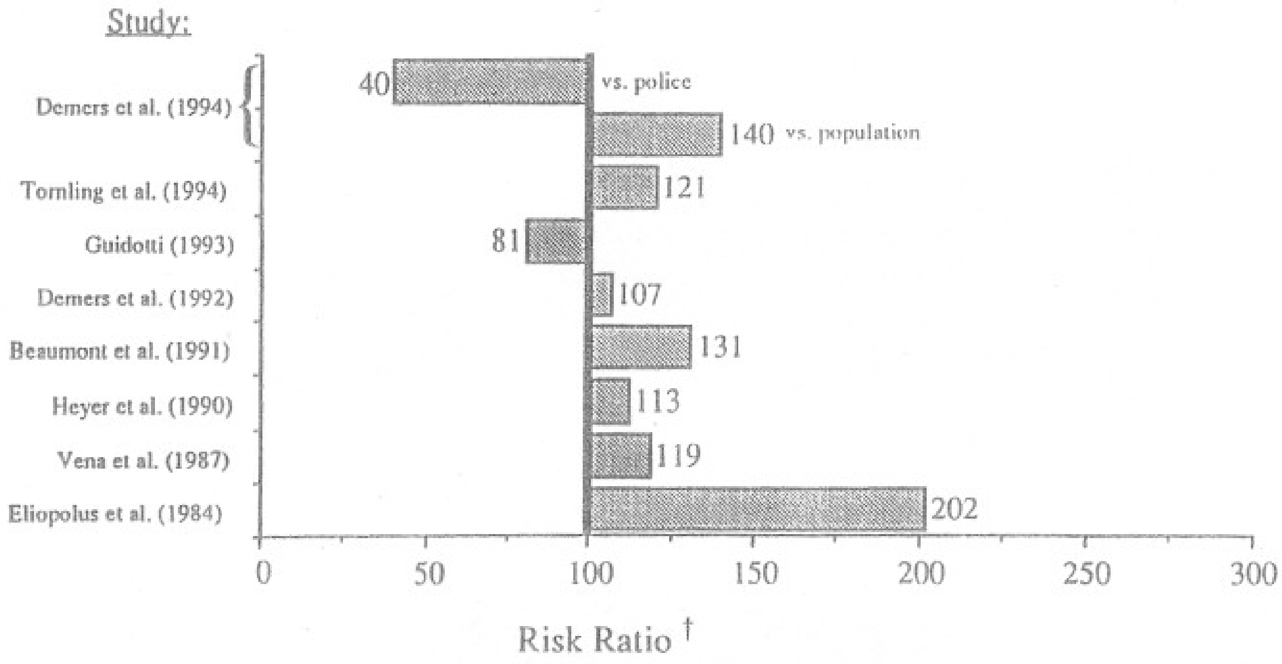
PANCREATIC CANCER AMONG FIREFIGHTERS



† Risk Ratio: SMR, PMR, or RR. Null value (no excess risk) equals 100.

Most studies showed a small to moderate increase in **cancer of the pancreas** among firefighters, although 1 study found that firefighters had more than 3 times the risk of police officers.

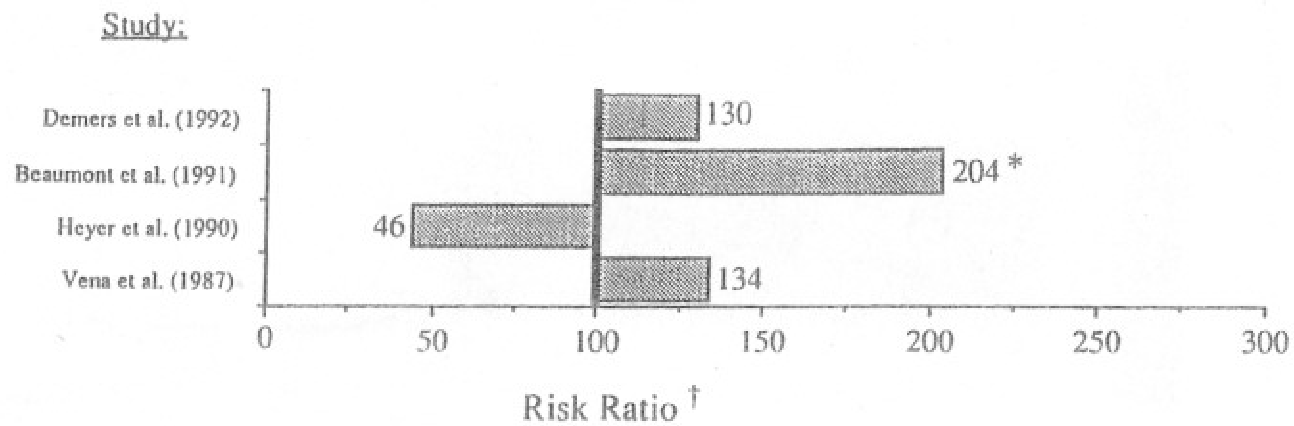
STOMACH CANCER AMONG FIREFIGHTERS



† Risk Ratio: SMR, PMR, or RR. Null value (no excess risk) equals 100.

This graph demonstrates that firefighters have consistently been shown to have higher rates of stomach cancer than the general public.

ESOPHAGEAL CANCER AMONG FIREFIGHTERS

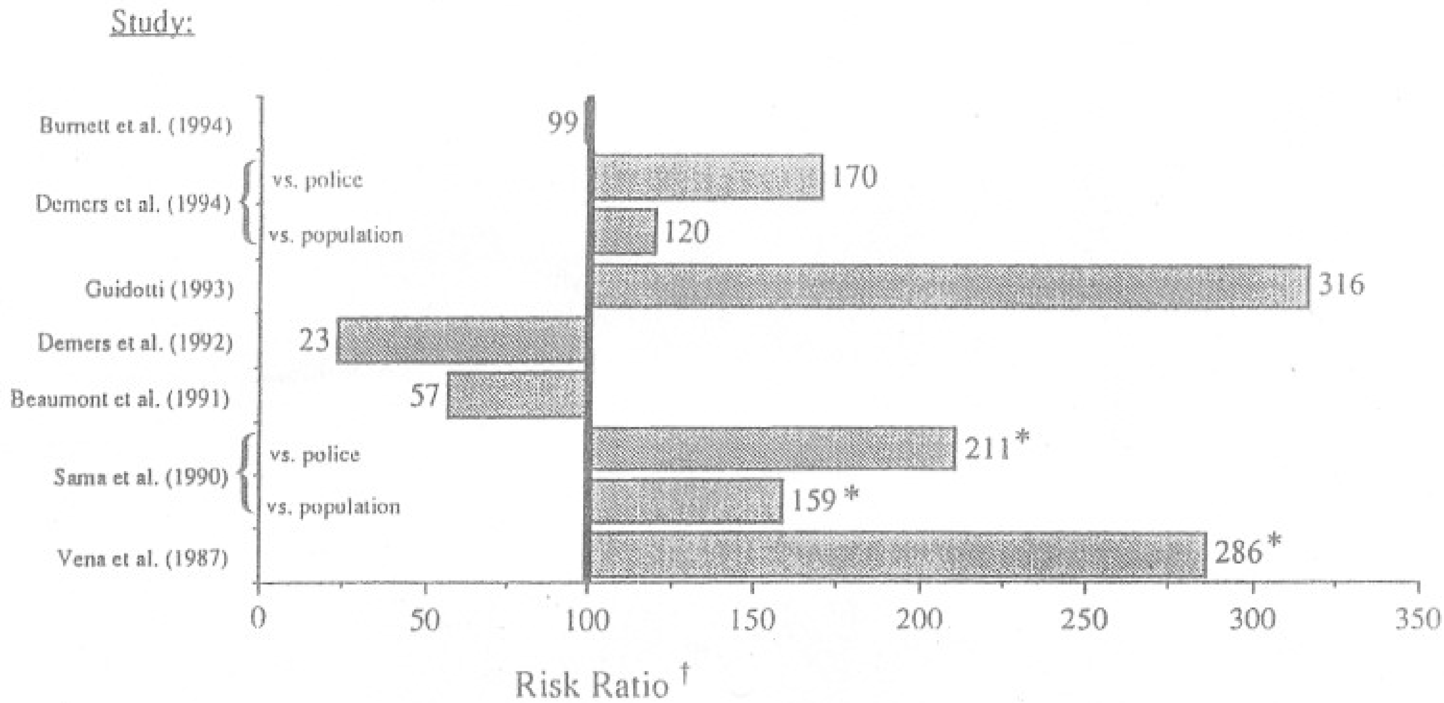


† Risk Ratio: SMR, PMR, or RR. Null value (no excess risk) equals 100.

* Statistically significant increase in risk.

The majority of studies that included **cancer of the esophagus** showed that firefighters are at increased risk.

BLADDER CANCER AMONG FIREFIGHTERS

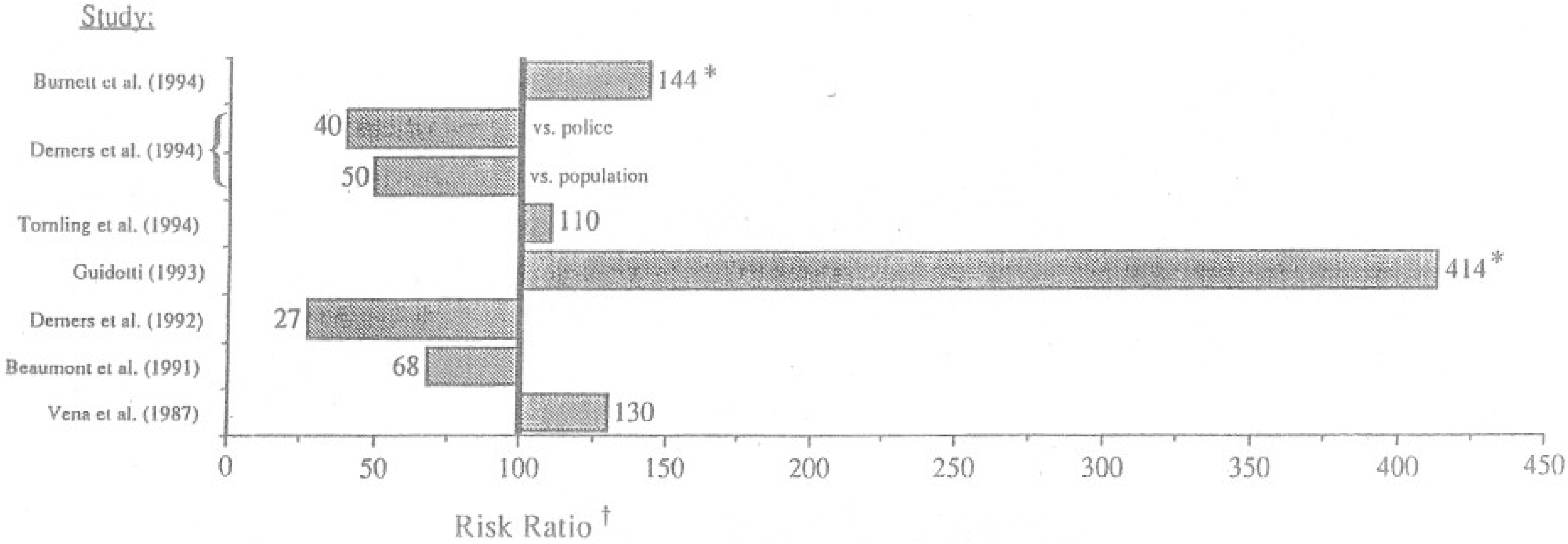


† Risk Ratio: SMR, PMR, or RR. Null value (no excess risk) equals 100.

* Statistically significant increase in risk.

The preponderance of evidence from these studies clearly implicates firefighting as a risk factor for bladder cancer. The excess risk among firefighters may be as high as 200%.

KIDNEY CANCER AMONG FIREFIGHTERS



†Risk Ratio: SMR, PMR, or RR. Null value (no excess risk) equals 100.

*Statistically significant increase in risk.

The excess risk of **kidney cancer** among firefighters was statistically significant in 2 studies. Some studies did find lower than average risk in firefighters.

E. CONCLUSIONS

The data in this report from the Mount Sinai School of Medicine lead to the following conclusions:

1. **Firefighters are exposed in their work to numerous carcinogens -- chemicals with the potential to cause cancer.** These carcinogens include benzene, formaldehyde, polycyclic aromatic hydrocarbons (PAH), asbestos and the multiple complex chemical compounds that arise in the combustion of synthetics and plastics.

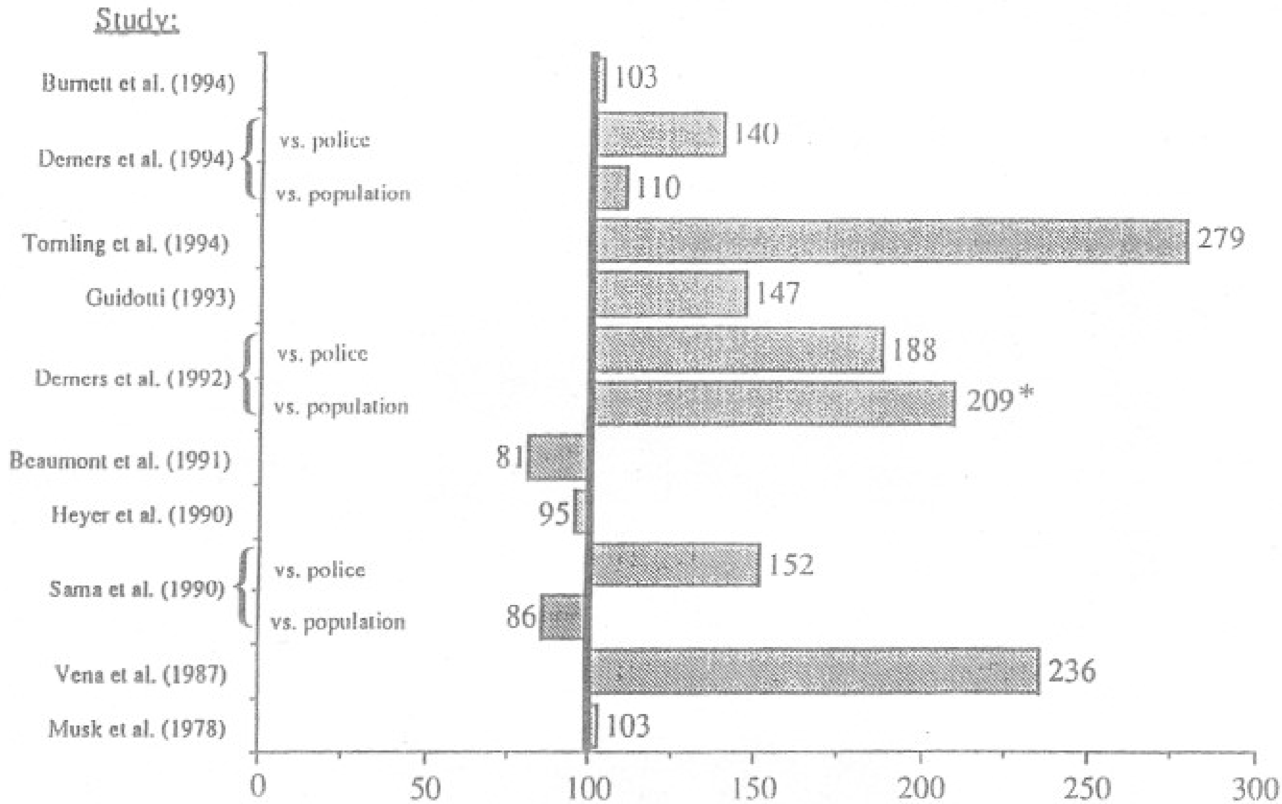
2. **Firefighters have been shown to be at increased risk of numerous cancers including leukemia, lymphoma, multiple myeloma, melanoma, and cancer of the urinary tract, stomach, colon, rectum, prostate and brain.**

3. **The carcinogenic hazards of the majority of chemicals to which firefighters are exposed in their work have never been tested.** Little is known about many of the pyrolysis products of these chemical agents. In consequence, firefighters are subjected to many unknown hazards.

4. **Firefighters in New York City are especially heavily exposed to chemical carcinogens**, because of the nature of buildings in New York City, the density of buildings and the high-rise structure of these buildings.

5. **The full extent of the problem of chemical carcinogens in firefighters has not yet been defined.** Small study size, inadequate characterization of exposure, inadequate diagnosis of work-related cancer and insufficient toxicity testing of chemicals encountered by firefighters are all factors that contribute to under-recognition of the true extent of the problem of chemical carcinogens in firefighters. The fact that increased cancer risk has been confirmed in the many studies conducted to date reflects the carcinogenic hazards encountered by firefighters in their work.

BRAIN CANCER AMONG FIREFIGHTERS



†Risk Ratio: SMR, PMR, or RR. Null value (no excess risk) equals 100.

*Statistically significant increase in risk.

Several studies have found elevated risk of brain cancer among firefighters. Generally, this excess risk occurs among younger firefighters and within 15-30 years of hire, i.e., after a relatively short latency period.

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