

# The burden of occupational cancer in Great Britain

## Overview report

Prepared by **Imperial College London**, the **Institute of Environment and Health**, the **Health and Safety Laboratory** and the **Institute of Occupational Medicine** for the Health and Safety Executive 2010

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The aim of this project was to produce an updated estimate of the current burden of occupational cancer specifically for Great Britain. The primary measure of the burden of cancer used in this project was the attributable fraction (AF) i.e. the proportion of cases that would not have occurred in the absence of exposure; this was then used to estimate the attributable numbers. This involved obtaining data on the risk of the disease due to the exposure of interest, taking into account confounding factors and overlapping exposures, and the proportion of the target population exposed over the period in which relevant exposure occurred. Estimation was carried out for occupational exposures classified by the International Agency for Research on Cancer (IARC) as group 1 (established) and 2A carcinogens (probable).

5.3% (8023) cancer deaths were attributable to occupation in 2005 (men: 8.2% (6366); women 2.3% (1657)). Attributable estimates for total cancer registrations are 13694 (4.0%); and for men: 10074 (5.7%) and women 3620 (2.1%). Occupational attributable fractions are over 2% for mesothelioma, sinonasal, lung, nasopharynx, breast, non-melanoma skin cancer, bladder, oesophagus, soft tissue sarcoma and stomach cancers. Asbestos, shift work, mineral oils, solar radiation, silica, diesel engine exhaust, coal tars and pitches, occupation as a painter or welder, dioxins, environmental tobacco smoke, radon, tetrachloroethylene, arsenic and strong inorganic mists each contribute 100+ registrations. Industries/occupations with high cancer registrations include construction, metalworking, personal/household services, mining, land transport, printing/publishing, retail/hotels/restaurants, public administration/defence, farming and several manufacturing sectors. 56% of cancer registrations in men are attributable to work in the construction industry (mainly mesotheliomas, lung, bladder and non-melanoma skin cancers) and 54% of cancer registrations in women are attributable to shift work (breast cancer).

This project is the first to quantify in detail the burden of cancer due to occupation specifically for GB. There are several sources of uncertainty in the estimates, including exclusion of other potential carcinogenic agents, inaccurate or approximate data and methodological issues. On balance, the estimates are likely to be a conservative estimate of the total attributable burden. Forthcoming reports will present the results for; estimates of Disability-Adjusted Life Years; methods to predict future estimates of the occupational cancers with examples based on important hazards; and the results of sensitivity analysis of these estimates to sources of uncertainty and bias.

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## EXECUTIVE SUMMARY

### INTRODUCTION

HSE wishes to develop appropriate practical measures to reduce the incidence of occupational cancer in Great Britain; they currently rely on estimates of the effects of occupation on cancer mortality in the US made by Doll & Peto in 1981 (4% of all US cancer deaths with an uncertainty range of 2% to 8%). The overall aims of this project were:

- to produce an updated estimate of the current burden of occupational cancer specifically for Great Britain
- to produce an estimate of the future occupational cancer burden in Great Britain based on recent and current exposures, together with the method for updating this in future
- where the data are sufficiently detailed, to break any headline estimates down into exposure-cancer combinations

This report presents an overview of the results of the current burden of cancer due to occupational carcinogens and circumstances in Great Britain (GB) together with a summary of the methodology developed and the data used.

### METHODOLOGY

The primary measure of the burden of cancer used in this project was the attributable fraction (AF) i.e. the proportion of cases that would not have occurred in the absence of exposure; this was then used to estimate the attributable numbers. The AF requires the risk of the disease due to the exposure of interest and the proportion of the target population exposed. Estimation was carried out for 2005 for mortality and 2004 for cancer incidence for occupational exposures for classified by the International Agency for Research on Cancer (IARC) as group 1 (established) and 2A carcinogens (probable).

Risk estimates, adjusted where appropriate for confounders, were obtained from key studies, meta-analyses or pooled studies, taking into account study quality. Dose-response risk estimates were generally not available in the epidemiological literature nor were proportions of those exposed at different levels of exposure over time available for the working population in GB. However, where possible risk estimates were obtained for an overall 'lower' level and an overall 'higher' level of exposure to the agents of concern and matched appropriately to the exposure scenario in question. The risk estimates for occupational exposure to ionising radiation were derived using generalized linear dose response models of excess relative risk per unit of cumulative radiation dose from the United Nations Scientific Committee on the Effects of Atomic Radiation.

The period during which exposure occurred that was relevant to the development of the cancer in the target year 2005 was defined as the risk exposure period (REP). For solid tumours a latency of 10-50 years was assumed giving a REP of 1956-1995; for haematopoietic neoplasms 0-20 year's latency was assumed giving a REP of 1986-2005. The proportion of the population ever exposed to each carcinogenic agent or occupation in the REP was obtained from the ratio of the numbers ever exposed to the carcinogens of interest in each relevant industry/occupation within GB over the total number of people ever employed. National data were used to obtain these. Account was taken of changes in numbers employed in the primary and manufacturing industry and service sectors in GB over the REP and adjustment was made where appropriate for employment turnover over the period.

## RESULTS

The overall burden in GB attributable to the occupational carcinogens considered was 5.3% (based on deaths (8.2% for men and 2.3% in women). Numbers of attributable deaths are 8019 overall (6362 for men, 1657 for women) and numbers of attributable cancer registrations are 13679 overall (10063 for men, 3616 for women). The AFs by cancer site range from less than 0.01% to 95% overall, the most important cancer sites for occupational attribution being, for men, mesothelioma (97%), sinonasal (46%), lung (21.1%), bladder (7.1%) and NMSC (7.1%), and for women mesothelioma (83%) sinonasal (20.1%), lung (5.3%), breast (4.6%) and nasopharynx (2.5%). Occupation also contributes 2% or more overall to cancers of the larynx, oesophagus, soft tissue sarcoma (STS) and stomach, with in addition for men melanoma of the eye (due to welding) and non-Hodgkin's lymphoma (NHL). Lung cancer contributes the largest number of attributable deaths for both men and women followed, for men, by mesothelioma, bladder, oesophageal and stomach cancers, and for women, by breast cancer, mesothelioma, bladder and oesophageal cancers. For attributable numbers of cancer registrations, the patterns differ between men and women; for men, lung cancer contributes the largest numbers of registrations followed by NMSC, mesothelioma, bladder, oesophageal and stomach cancers, non-Hodgkin's lymphomas and sinonasal cancer; for women breast cancer contributes the largest numbers of registrations followed by lung cancer, NMSC, mesothelioma, bladder cancer, non-Hodgkin's lymphoma, ovarian, sinonasal and oesophageal cancers.

Many carcinogenic exposures in the workplace affect multiple cancer sites. Asbestos contributes the most to both total attributable deaths and registrations (larynx, lung, mesothelioma, stomach). Others making a major contribution to attributable deaths and/or registrations include arsenic (lung), diesel engine exhaust (DEE) (bladder, lung), dioxins (lung), environmental tobacco smoke (ETS) encountered at work in non-smokers (lung), mineral oils (bladder, lung, non-melanoma skin cancer (NMSC), sinonasal), polycyclic aromatic hydrocarbons from coal tar and pitches (NMSC), radon from natural exposure in workplaces (lung), shift work, including flight personnel (breast), silica (lung), solar radiation (NMSC), strong inorganic acid mists (larynx, lung), tetrachloroethylene (cervix, non-Hodgkin's lymphoma, oesophagus), work as a painter (bladder, lung, stomach) and work as a welder (lung, melanoma of the eye due to ultra violet radiation).

Industry sectors contributing substantially to the total burden includes construction, land transport, manufacture of transport equipment, metal workers, mining, painters and decorators in the construction industry, personal and household services (this sector includes repair trades, laundries and dry cleaning, domestic services, hairdressing and beauty), printing and publishing, public administration and defence, roofers and road repairs, shift work, and wholesale and retail trades. The majority of industry sectors involve exposure to several carcinogens (many over 10) with construction and many of the manufacturing sectors involving potential exposure to between 15 and 20 carcinogens. There are several key exposures which give rise to substantial numbers of registrations across multiple industry sectors. Of note is the contribution of exposure to (i) asbestos, DEE, silica and solar radiation in the construction industry; (ii) asbestos, DEE, ETS (non-smokers), soots and tetrachloroethylene in personal and household services; (iii) asbestos and DEE in land transport (railway, road, pipelines); (iv) asbestos, DEE, silica and solar radiation in mining; (v) ETS (non-smokers) and solar radiation in public administration and defence; (vi) asbestos, ETS (non-smokers) and radon in the wholesale and retail trade, restaurants and hotels and (vii) dioxins, non-arsenical insecticides and solar radiation in farming.

## **DISCUSSION**

This project is the first to quantify in detail the burden of cancer due to occupation specifically for GB. The project highlights the impact of occupational exposures, together with the occupational circumstances and industrial areas where exposures to these agents occurred in the past, on population cancer morbidity and mortality. Our methodological approach was developed with advice, discussion and peer review from international experts, including IARC, throughout the project and at two international workshops. It takes account of issues such as latency and the period in which relevant exposure would occur, changes in workforce turnover and employment trends and the potential to be exposed to several carcinogens concurrently and at different levels. These methods have the potential to be adapted for use in other countries and extended to include social and economic impact evaluation.

However, assumptions made in our methodology and uncertainties and inaccuracies in the data may have introduced biases into our estimates. Inclusion of IARC group 2A carcinogens may have inflated our estimates; alternatively exclusion of IARC group 2B (possible) carcinogens and other suspected or unknown carcinogens may have led to an underestimation. Other caveats include inappropriate choice of risk estimates, imprecision in the risk estimates and estimates of proportions exposed, inaccurate assumptions about the risk exposure and latency periods, and in some cases a lack of separate risk (and/or cancer incidence) estimates for women.

Due to the long latent interval of many carcinogens the estimates of current burden are based on exposures occurring in the past. Many of these would have been considerably higher than today and there is evidence of continuing downward trends in the UK in many exposures. However, it should be noted that for many of the carcinogens a major contribution to the burden was made by a large number of workers exposed at low levels and low risk.

On-going work and future reports will address; estimation of the occupational cancer burden using measures such as years of life lost and Disability-Adjusted Life Years; the methods to predict future estimates of the occupational cancers with examples based on important hazards; and methods to assess the sensitivity of these estimates to sources of uncertainty and bias.



## 1.0 INTRODUCTION

In 1981 in their report to the US Congress, Doll & Peto presented a method of estimating the effects of occupation on cancer mortality in the US (Doll & Peto, 1981). The proportion of cancer they attributed to occupation was about 4% of all US cancer deaths with an uncertainty range of 2% to 8%. More recently they have produced a new estimate of 2% with a range of 1-5% and suggest that less than 1% is known to be avoidable by practicable ways (Doll and Peto, 2005). The Health and Safety Executive (HSE) has relied on the 1981 study to estimate the proportions of cancers in Great Britain (GB) due to occupational exposures, giving an estimate of around 6000 cancer deaths (uncertainty range 3000 to 12000) and 12000 cancer registrations (uncertainty range 6000 to 24000) currently occurring each year in GB. In a later overview of the epidemiology of cancer, Doll & Peto suggested that it is unlikely that occupational hazards account for more than two or three per cent of all fatal cancers in developed countries such as the UK, but they acknowledge that the quantitative evidence is uncertain and the estimate could be out by a factor of two (Doll & Peto, 2003).

HSE wishes to develop appropriate practical measures to reduce the incidence of occupational cancer in Great Britain. These measures could include improved risk assessment, chemical substitution, improved control measures and evidence of their effectiveness. It will be important that these can be employed in small- and medium-sized enterprises as well as larger businesses. Future strategies for deciding where HSE targets its action on workplace carcinogens through policy-making, advice and enforcement activity are dependent on a sound evidence base. This evidence base will also help determine HSE's priorities for preventing future disease.

It is acknowledged that the estimates of current burden of cancer due to occupational exposures are based on evidence and methodology that is over 25 years old, and that it is now appropriate that the validity of these estimates is reassessed using currently available scientific evidence.

The aims of this project carried out by Imperial College London in collaboration with the Health and Safety Laboratory (HSL), the Institute of Environment and Health (IEH) at Cranfield University and the Institute of Occupational Medicine (IOM) were:

- to produce an updated estimate of the current burden of occupational cancer in Great Britain
- to produce an estimate of the future occupational cancer burden in Great Britain based on recent and current exposures, together with the method for updating this in future
- to the extent that the data will allow, to break any headline estimates down into exposure-cancer combinations

These estimates will inform the HSE's ongoing deliberations, as part of the cancer project of the Long Latency Disease Programme, on the priorities for intervention on occupational carcinogens.

This report presents an overview of the results of the current burden of cancer due to occupational carcinogens and circumstances in GB together with a summary of the methodology developed and the data used. Separate technical reports for each cancer giving more details of the source data, cancer burden calculations, and statistical methodology will be made available on the HSE website during 2010. Other reports will be published including methods for predicting the future burden of occupational cancers due to recent exposures, and the application of these methods to priority carcinogens and exposure circumstances. Other measures of burden will be reported such as Years of Life Lost and Disability-Adjusted Life Years, as well as a report summarizing the

application of a sensitivity analyses to determine the biases and uncertainties surrounding these estimates of cancer burden.

## 2.0 METHODOLOGY

### 1.1 OVERVIEW OF THE STUDY DESIGN

For each cancer, information on the incidence, mortality and survival trends in GB was obtained and an overview of the aetiology and known and suspected causal factors, including occupationally related factors, was carried out. Estimation was carried out using 2005 data for mortality and 2004 for cancer incidence. Mortality data were obtained from the Office for National Statistics (ONS), and the General Register Office for Scotland. Cancer incidence data were obtained from ONS, Cancer Statistics, Registrations, Series MB1 for England, the Scottish Cancer Registry, and the Welsh Cancer Intelligence and Surveillance Unit.

The attributable fraction (AF) i.e. the proportion of cases that would not have occurred in the absence of an occupational exposure was estimated; this was then used to estimate the attributable numbers. There are several methods for estimating the AF but all depend on knowledge of the risk of the disease due to the exposure of interest and the proportion of the target population exposed (Steenland *et al*, 2006).

### 2.2 RISK ESTIMATES

Risk estimates were obtained from key studies, meta-analyses or pooled studies, taking into account quality (including relevance to GB, sample size, extent of control for confounders, adequacy of exposure assessment, and clarity of case definition). Studies could be industry-based cohort studies or population-based case-control studies.

Factors that were considered for the choice of study included:

- Representativeness
  - Broad based and representative of the occupations or industrial exposures in GB
  - Included separate evaluations for men and women if relevant
- Study quality
  - Large sample size
  - Control for confounders i.e. adjusted analyses carried out
  - Adequate exposure assessment in the study
  - Standardised diagnosis of cancer cases
  - Appropriate comparison or a control population
- Portability, for which there are three key issues:
  - UK study or similar population, so that the source study and target (GB) exposures match on types and levels of exposure
  - Up-to-date study, so that the relevant period of exposure in the source population is not so long ago that the exposures on which the risk estimates were based no longer match exposures in the target relevant exposure period
  - Comparable distribution of known confounders within GB population.

Where possible risk estimates were selected that were adjusted for important confounders or non-occupational risk factors e.g. smoking for lung cancer, smoking and alcohol use for laryngeal cancer. Where only a narrative review was available giving a range of risk estimates from several relevant studies a combined estimate of the relative risks (RR) was calculated based on a random- (for heterogeneous RRs) or fixed- (for homogeneous RRs) effects model. Formal systematic reviews and meta-analyses were carried out to estimate risk estimates for laryngeal and stomach cancers related to asbestos exposure.

Dose-response risk estimates were generally not available in the epidemiological literature nor were proportions of those exposed at different levels of exposure over time available for the working population in GB. However, where possible risk estimates were obtained for an overall 'lower' level and an overall 'higher' level of exposure to the agents of concern and matched appropriately to the exposure scenario in question.

The risk estimates for occupational exposure to ionising radiation were derived using generalized linear dose response models of excess relative risk per unit of cumulative radiation dose from the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 2006). Cumulative lifetime dose was estimated using data from the Central Index of Dose Information (CIDI) (HSE, 1998). For aircrew, who are not covered by CIDI, the mean total lifetime radiation dose per pilot was obtained from a large cohort study of European airline pilots (Langner *et al*, 2004) and combined with numbers employed obtained from the British Airways Stewards and Stewardesses Union (BASSA, 2008) and the Labour Force Survey.

A substantial proportion of the excess is likely to occur in the large number of workers with low exposures for whom estimates of average risks are inevitably unreliable. Where no risk estimate could be identified for very low/background levels of exposure for a particular carcinogen, a RR was estimated for the 'lower exposed' group by (i) taking the harmonic mean of all the available ratios of 'higher' to 'lower' RR estimates for cancer-exposure pairs for which data were available, (ii) applying this average ratio to the 'higher' level estimate for the carcinogen to obtain a 'lower' level RR estimate for the carcinogen. If the resulting RR estimate was less than 1, RR was set to one.

### **2.3 EXPOSED POPULATION ESTIMATION**

The period during which exposure occurred that was relevant to the development of the cancer in the target year 2005 was defined as the risk exposure period (REP). For solid tumours a latency of 10-50 years was assumed giving a REP of 1956-1995; for haematopoietic neoplasms 0-20 year's latency was assumed giving a REP of 1986-2005. The proportion of the population ever exposed to each carcinogenic agent or occupation in the REP was obtained from the ratio of the numbers ever exposed to the carcinogens of interest in each relevant industry/occupation within GB over the total number of people ever employed (Equation 4 in the Statistical Appendix).

If the study from which the risk estimates were obtained was population based, an estimate of the proportion of the population exposed was derived directly from the study data, although such studies were rarely available in practice for GB. If the risk estimate was obtained from an industry-based study, national data sources such as the CARcinogen EXposure database (CAREX) (Pannett *et al*, 1998), the UK Labour Force Survey (LFS) (LFS, 2009) and Census of Employment (ONS, 2009) were used. CAREX was used for estimating the numbers of the GB population ever exposed to a carcinogen by industry sector. As highlighted above data are not available on the levels of exposure in all industry sectors for all the carcinogens considered, nor the numbers exposed at these levels. The industry sectors were thus allocated to 'higher' or 'lower' exposure categories assuming distributions of exposure and risk that corresponded broadly to those of the studies from which the risk estimates were selected. The initial allocations were based on the judgment of an experienced human exposure scientist; each assessment was then independently peer-reviewed and if necessary, a consensus assessment agreed. Data from CAREX are not differentiated by sex; 1991 Census data by industry and occupation were used to estimate the relative proportions of men and women exposed. The LFS and Census of Employment data were used to estimate numbers ever employed in specific occupations e.g. welder, painter etc., and for specific industries for carcinogens not included in CAREX.

CAREX data for GB relate only to the period 1990-93. For the LFS and CoE an available year was chosen to represent numbers employed about 35 years before the target year of 2005, as this was thought to represent a 'peak' latency for the solid tumours, and is also close to the mid-point of the REP for estimating numbers ever exposed across the period (for which a linear change in employment levels was implicitly assumed). Where the Census of Employment was used, the data are for 1971. Where the LFS was used, the first year available used was 1979 for solid tumours, and 1991 for short latency cancers.

When CAREX data were used adjustment factors were applied to take account of the change in numbers employed in the primary and manufacturing industry and service sectors in GB over the REP. Adjustment for employment turnover over the period for grouped main industry sectors was also carried out (see equation 3 in the Statistical Appendix). Ideally this requires full national starter and leaver data across the REP for all industry sectors. In the absence of this quality of data, estimating turnover directly using new starters in years within the REPs gives the best approximation for the purpose of estimating those ever exposed. This method estimates starters in the past year as a proportion of the average number employed (Gregg and Wadsworth, 2002). As exposure in occupational epidemiological studies is usually defined as at least one year, we have adapted this to exclude short-term labour turnover. New starters in the past year who are expected to remain employed for at least one year were taken as a proportion of all those expected to be employed for at least 1 year. This was estimated as the number recorded as employed for between 1 and 2 years divided by the total employed for at least one year using LFS data averaged over the REP.

## 2.4 STATISTICAL ANALYSIS

The AFs have been calculated on a cancer by cancer basis. To estimate the AFs for each cancer/occupational carcinogen Levin's method was used if risk estimates came from an industry-based study or a review or meta-analysis together with estimates of the proportion of the population exposed from independent national sources of data (Levin, 1953). Miettinen's method was used if risk estimates and proportion of cases exposed came from a population-based study (Miettinen, 1974) (equations 1 and 2 respectively in the Statistical Appendix). For each AF, a random error confidence interval was calculated using Monte Carlo simulations (Steenland and Armstrong, 2006). The AFs were applied to total numbers of cancer specific deaths (2005) and cancer registrations (2004) for ages that could have been exposed during the REP to give attributable numbers. Where risk estimates were only available from mortality studies AFs derived from these were used for estimation of attributable registrations and vice versa. Similarly if separate AFs for women could not be estimated those for men or for men and women combined were used.

The AF for mesothelioma was derived directly from several UK mesothelioma studies that suggest between 96% and 98% of male mesothelioma cases are due to occupational or paraoccupational (e.g. exposure from living near an asbestos factory or handling clothes contaminated due to occupational exposure) exposure (Yates *et al*, 1997; Howel *et al*, 1997; Rake *et al*, 2009). Combining the results from Rake *et al* (2009) with those from two studies in which results were reported separately for females (Goldberg *et al*, 2006; Spirtas *et al*, 1994) gave estimates of 75%-90% for females. The ratio of asbestos related lung cancer to mesothelioma deaths has been suggested to be between two-thirds and one (Darnton *et al*, 2006). Rather than using our standard method for the estimation of numbers of lung cancers attributable to asbestos, we therefore used a ratio of 1:1, lung cancer to mesothelioma deaths; this takes into account of the impact that past levels of exposure to asbestos are having on the current incidence by the

direct link to mesothelioma deaths that are still climbing whereas lung cancer in general is declining due to the reduction in smoking. This assumes, however, that lung cancer has a similar pattern of latency as mesothelioma. The total lung cancers attributable to asbestos were allocated between industries by using estimates of relative risk for 'higher' and 'lower' level exposed (from Goodman et al, 1999) and proportions ever exposed by industry sector (based on CAREX) combined as weights.

For lung cancer associated with radon exposure from natural sources, estimates of rates of lung cancer due to exposure to radon in domestic buildings (NRPB 2000) were applied to estimates of the time employees spend in workplaces where radon exposure occurs.

AFs for all the relevant carcinogenic agents and occupational circumstances were combined into a single estimate of AF for each separate cancer. To take account of potential multiple exposures, strategies including partitioning exposed numbers between overlapping exposures or estimating only for the 'dominant' carcinogen with the highest risk were used. The IARC Monograph process has been taking place over many years and has resulted in overlap between substances evaluated. For lung cancer, for example, there are 32 occupations or carcinogenic agents evaluated by IARC. AFs were estimated for 21 of these; for example, substances such as coal-tars and pitches and processes such as coal gasification and coke production were included within our evaluation of Polycyclic Aromatic Hydrocarbons (PAH). Where exposure to multiple carcinogens remained it was assumed that the exposures were independent of one another and that their joint carcinogenic effects were multiplicative. The AFs were then combined to give an overall AF for that cancer using a product sum (equation 5 in the Statistical Appendix). An overall AF for all cancers was estimated by summing the attributable numbers for each, and dividing by the total number of cancers in GB.

## 3.0 RESULTS

The study has quantified for the first time the impact of occupation on the burden of cancer in Britain for all cancer sites and the carcinogens which IARC have classified as having sufficient (group 1) or limited (group 2A) evidence in humans. Estimates of attributable fractions, attributable numbers of deaths (for 2005) and attributable numbers of cancer registrations (for 2004) have been made for:

1. for males and female separately and for the total;
2. for 24 separate cancer sites and the total
3. for 41 separate carcinogens or occupational circumstances
4. for over 60 separate industry sectors.

This report presents summary tables for these results. More detailed results are available in MS Excel tables on the HSE website and will be available in the technical reports for the individual cancer sites.

### 3.1 ATTRIBUTABLE FRACTIONS AND NUMBERS BY CANCER SITE

The overall burden by cancer site (AFs, attributable numbers (ANs) and 95% confidence intervals) is given in Table 1A. 8.2% (n = 6362) of cancer deaths in 2005 in men and 2.3% (n = 1657) in women in Britain have been estimated to be due to occupation giving an overall AF of 5.3% (n = 8019). The combined AFs for registrations are 5.7% (n = 10063) for men in 2004 and 2.1% (n = 3616) for women giving an overall AF based on registrations of 4.0% (n = 13679). If only agents and occupations classified by IARC as group 1 and having strong evidence of carcinogenicity in humans are considered, the overall burden reduces to 4.0% (5123 total deaths, 8277 total registrations) (Table 1B). Only 9 cancer sites are involved (bladder, larynx, leukaemia, liver, lung, mesothelioma, non-melanoma skin cancer (NMSC), sinonasal and thyroid). The dominance of asbestos exposure and mesothelioma, asbestos and the many other group 1 carcinogens affecting lung cancer and solar radiation and NMSC means that the reduction in the AF and attributable numbers for men (6.6%, 5123 deaths, 8277 registrations) is far less than for women (1.2%, 862 deaths, 1313 registrations) for whom shift work is most dominant.

In general, attributable fractions and numbers are higher for men than for women, due mainly to the higher proportions of males exposed to occupational carcinogens. The difference between the numbers of attributable deaths and registrations reflects the varying survival from cancer with mortality and registration numbers being similar for poor survival cancers such as lung cancer and mesothelioma; in contrast the difference is much greater for cancers such as breast cancer where survival is improving and for NMSC, which is rarely fatal.

The AFs by cancer site range from less than 0.01% to 95% overall, the most important cancer sites for occupational attribution being, for men, mesothelioma (97%), sinonasal (46%), lung (21.1%), bladder (7.1%) and NMSC (7.1%), and for women mesothelioma (83%) sinonasal (20.1%), lung (5.3%), breast (4.6%) and nasopharynx (2.5%). Occupation also contributes 2% or more overall to cancers of the larynx, oesophagus, soft tissue sarcoma (STS) and stomach, with in addition for men melanoma of the eye (due to welding) and non-Hodgkin's lymphoma (NHL).

Lung cancer contributes the largest number of attributable deaths for both men and women followed, for men, by mesothelioma, bladder, oesophageal and stomach cancers, and for women, by breast cancer, mesothelioma, bladder and oesophageal cancers. For attributable numbers of cancer registrations, the patterns differ between men and women; for men, lung cancer

contributes the largest numbers of registrations followed by NMSC, mesothelioma, bladder, oesophageal and stomach cancers, non-Hodgkin's lymphomas and sinonasal cancer; for women breast cancer contributes the largest numbers of registrations followed by lung cancer, NMSC, mesothelioma, bladder cancer, non-Hodgkin's lymphoma, ovarian, sinonasal and oesophageal cancers.

**Table 1A** Estimated attributable fractions, deaths and registrations by cancer site in 2005 (deaths) and 2004 (registrations)

Cancer Site	Attributable Fraction (%) (95% Confidence Interval)			Attributable Numbers (95% Confidence Interval)					
				Deaths (2005)			Registrations (2004)		
	Male	Female	Total (Based on Deaths)	Male	Female	Total	Male	Female	Total
Bladder	7.1 (4.6, 9.7)	1.9 (1.3, 3.9)	5.3 (3.4, 7.7)	215 (139, 296)	30 (21, 62)	245 (159, 358)	496 (321, 684)	54 (37, 110)	550 (357, 795)
Bone	0.04	0.01	0.02	0	0	0	0	0	0
Brain	0.5 (0.1, 1.1)	0.1 (0, 0.2)	0.4 (0.0, 0.7)	10 (1, 20)	1 (0, 3)	11 (1, 23)	12 (1, 25)	2 (0, 4)	14 (1, 28)
Breast		4.6 (3.3, 6.0)	4.6 (3.3, 6.0)		555 (397, 727)	555 (397, 727)		1969 (1407, 2579)	1969 (1407, 2579)
Cervix		0.7 (0.0, 2.1)	0.7 (0.0, 2.1)		7 (0, 22)	7 (0, 22)		18 (1, 56)	18 (1, 56)
Kidney	0.04 (0, 0.16)	0.04 (0, 0.14)	0.04 (0, 0.15)	1 (0, 3)	1 (0, 2)	1 (0, 5)	2 (0, 7)	1 (0, 4)	3 (0, 10)
Larynx	2.9 (1.4, 5.7)	1.6 (0.6, 3.5)	2.6 (1.2, 5.2)	17 (8, 34)	3 (1, 6)	20 (9, 40)	50 (24, 99)	6 (2, 13)	56 (26, 112)
Leukaemia <sup>a</sup>	0.9 (0.2, 3.5)	0.5 (0.1, 4.5)	0.8 (0.2, 3.9)	18 (4, 71)	6 (1, 49)	24 (5, 120)	31 (7, 118)	9 (1, 80)	40 (8, 199)
Liver	0.2 (0.1, 0.3)	0.1 (0.1, 0.2)	0.2 (0.1, 0.3)	4 (2, 6)	2 (1, 2)	5 (3, 8)	4 (2, 6)	2 (1, 2)	5 (3, 8)
Lung	21.1 (19.2, 24.7)	5.3 (4.3, 6.9)	14.5 (13.0, 17.2)	4024 (3659, 4696)	726 (592, 946)	4749 (4251, 5643)	4632 (4212, 5406)	816 (666, 1063)	5447 (4877, 6469)
Lympho-haematopoietic	0.004 (0, 0.014)	0.002 (0, 0.007)	0.003 (0, 0.011)	0 (0, 1)	0 (0, 0)	0 (0, 1)	0 (0, 1)	0 (0, 0)	1 (0, 2)
Melanoma (eye)	2.9 (0.6, 6.6)	0.4 (0.1, 1.0)	1.6 (0.3, 3.6)	1 (0, 3)	0 (0, 0)	1 (0, 3)	6 (1, 13)	1 (0, 2)	6 (1, 16)
Mesothelioma	97.0 (96.0, 98.0) <sup>b</sup>	82.5 (75.0, 90.0) <sup>b</sup>	94.9 (93.0, 96.9) <sup>b</sup>	1699 (1681, 1717)	238 (216, 260)	1937 (1898, 1976)	1699 (1681, 1717) <sup>c</sup>	238 (216, 260) <sup>c</sup>	1937 (1898, 1976) <sup>c</sup>
Multiple Myeloma	0.4 (0, 1.0)	0.1 (0, 0.3)	0.3 (0, 0.7)	5 (0, 10)	1 (0, 2)	6 (0, 12)	8 (0, 18)	2 (0, 3)	10 (0, 21)
Nasopharynx	11.0 (2.3, 47.9)	2.5 (0.6, 6.8)	8.2 (1.8, 34.3)	7 (2, 32)	1 (0, 2)	8 (2, 33)	14 (3, 61)	2 (0, 4)	16 (3, 65)
NHL	2.1 (0, 6.9)	1.1 (0.1, 2.9)	1.7 (0, 5.4)	43 (0, 138)	14 (1, 37)	57 (1, 176)	102 (0, 328)	39 (3, 101)	140 (3, 430)

Cancer Site	Attributable Fraction (%) (95% Confidence Interval)			Attributable Numbers (95% Confidence Interval)					
				Deaths (2005)			Registrations (2004)		
	Male	Female	Total (Based on Deaths)	Male	Female	Total	Male	Female	Total
NMSC <sup>d</sup>	7.1 (1.3, 15.1)	1.1 (0.0, 2.9)	4.6 (0.8, 10.0)	21 (4, 44)	2 (0, 6)	23 (4, 50)	2576 (481, 5475)	352 (0, 900)	2928 (481, 6375)
Oesophagus	3.3 (1.5, 7.5)	1.1 (0.3, 2.8)	2.5 (1.1, 5.9)	156 (70, 358)	28 (8, 70)	184 (78, 429)	159 (71, 365)	29 (9, 74)	188 (80, 439)
Ovary		0.5 (0, 1.2)	0.5 (0, 1.2)		23 (0, 52)	23 (0, 52)		33 (0, 76)	33 (0, 76)
Pancreas	0.02 (0, 0.07)	0.01 (0, 0.04)	0.01 (0, 0.05)	1 (0, 2)	0 (0, 1)	1 (0, 4)	1 (0, 2)	0 (0, 1)	1 (0, 4)
Sinonasal	46.0 (27.3, 74.0)	20.1 (14.4, 31.6)	34.4 (21.5, 54.8)	29 (17, 47)	10 (8, 16)	39 (25, 63)	101 (60, 162)	32 (23, 50)	133 (83, 212)
STS	3.4 (0, 11.4)	1.1 (0, 3.8)	2.4 (0, 8.1)	11 (0, 36)	3 (0, 9)	13 (0, 45)	22 (0, 75)	4 (0, 15)	27 (0, 90)
Stomach	3.0 (1.5, 5.1)	0.3 (0.1, 0.5)	2.0 (1.0, 3.4)	102 (52, 176)	6 (3, 11)	108 (55, 187)	149 (77, 258)	9 (4, 15)	158 (81, 274)
Thyroid	0.12	0.02	0.05	0	0	0	1	0	1
Total Based on deaths	<b>8.2 (7.2, 9.9)</b>	<b>2.3 (1.7, 3.2)</b>	<b>5.3 (4.6, 6.6)</b>	<b>6362 (5641, 7690)</b>	<b>1657 (1249, 2289)</b>	<b>8019 (6891, 9983)</b>			
Total Based on registrations	<b>5.7 (3.9, 8.4)</b>	<b>2.1 (1.4, 3.2)</b>	<b>4.0 (2.7, 5.9)</b>				<b>10063 (6941 14822)</b>	<b>3616 (2370, 5413)</b>	<b>13679 (9310, 20235)</b>
Total cancers in GB in ages 15+				<b>77912</b>	<b>72212</b>	<b>150124</b>	<b>175399</b>	<b>168184</b>	<b>343583</b>

NHL = Non-Hodgkin's lymphoma; NMSC = non-melanoma skin cancer; STS = soft tissue sarcoma

<sup>a</sup> AF applicable to all leukaemias

<sup>b</sup> Includes cases described as due to paraoccupational or environmental exposure to asbestos.

<sup>c</sup> Taken as equal to attributable deaths for this short survival cancer.

<sup>d</sup> Based on registrations

Totals do not always sum across rows due to rounding error

Confidence Intervals not estimated for cancers attributed to ionizing radiation, as they are not yet available for the excess relative risk models used (UNSCEAR 2006)

**Table 1B** Estimated attributable fractions, deaths and registrations by cancer site in 2005 (deaths) and 2004 (registrations) for agents and occupations classified as IARC group 1 with 'strong' evidence of carcinogenicity in humans

Cancer Site	Attributable Fraction (%) (95% Confidence Interval)			Attributable Numbers (95% Confidence Interval)					
				Deaths (2005)			Registrations (2004)		
	Male	Female	Total (Based on Deaths)	Male	Female	Total	Male	Female	Total
Bladder	0.8 (0.7,3.0)	0.6 (0.5,2.9)	<b>0.7 (0.6,2.8)</b>	24 (20, 91)	10 (9, 39)	<b>34 (29, 130)</b>	55 (47, 211)	18 (16, 70)	<b>73 (63, 280)</b>
Bone	0	0	<b>0</b>	0	0	<b>0</b>	0	0	<b>0</b>
Brain	0	0	<b>0</b>	0	0	<b>0</b>	0	0	<b>0</b>
Breast		0	<b>0</b>		0	<b>0</b>		0	<b>0</b>
Cervix	0	0	<b>0</b>	0	0	<b>0</b>	0	0	<b>0</b>
Kidney	0	0	<b>0</b>	0	0	<b>0</b>	0	0	<b>0</b>
Larynx	2.3 (0.8,5.1)	1.5 (0.5, 3.4)	<b>2.1 (0.8, 4.8)</b>	14 (5, 31)	2 (1, 5)	<b>16 (6, 37)</b>	40 (15, 89)	6 (2, 12)	<b>46 (17, 102)</b>
Leukaemia <sup>a</sup>	0.1 (0, 2.0)	0.2 (0.1, 3.9)	<b>0.2 (0, 2.6)</b>	3 (0, 40)	2 (0, 36)	<b>5 (1, 75)</b>	5 (1, 70)	4 (0, 55)	<b>8 (1, 124)</b>
Liver	0.2 (0.1,0.3)	0.1 (0, 0.1)	<b>0.1 (0.1, 0.2)</b>	2 (1, 4)	1 (0, 2)	<b>3 (1, 6)</b>	2 (1, 4)	1 (0, 2)	<b>3 (2, 6)</b>
Lung	17.6 (15.5, 19.4)	4.4 (3.5, 5.4)	<b>12.0 (10.2, 13.9)</b>	3347 (2945,3687)	599 (527,660)	<b>3946 (3472,4346)</b>	3853 (3390,4244)	673 (592, 741)	<b>4526 (3982, 4985)</b>
Lympho-haematopoietic	0	0	<b>0</b>	0	0	<b>0</b>	0	0	<b>0</b>
Melanoma (eye)	0	0	<b>0</b>	0	0	<b>0</b>	0	0	<b>0</b>
Mesothelioma	97.0 (96.0, 98.0) <sup>b</sup>	82.5 (75.0, 90.0) <sup>b</sup>	<b>94.9 (93.0, 96.9)<sup>b</sup></b>	1699 (1681, 1717)	238 (216, 260)	<b>1937 (1898, 1976)</b>	1699 (1681, 1717) <sup>c</sup>	238 (216, 260) <sup>c</sup>	<b>1937 (1898, 1976)<sup>c</sup></b>
Multiple Myeloma	0	0	<b>0</b>	0	0	<b>0</b>	0	0	<b>0</b>
Nasopharynx	0	0	<b>0</b>	0	0	<b>0</b>	0	0	<b>0</b>
NHL	0	0	<b>0</b>	0	0	<b>0</b>	0	0	<b>0</b>

Cancer Site	Attributable Fraction (%) (95% Confidence Interval)			Attributable Numbers (95% Confidence Interval)					
				Deaths (2005)			Registrations (2004)		
	Male	Female	Total (Based on Deaths)	Male	Female	Total	Male	Female	Total
NMSC <sup>d</sup>	7.1 (1.3, 15.1)	1.1 (0.0, 2.9)	<b>4.6 (0.8, 10.0)</b>	21 (4, 44)	2 (0, 6)	<b>23 (4, 50)</b>	2576 (481, 5475)	352 (0, 900)	<b>2928 (481, 6375)</b>
Oesophagus	0	0	<b>0</b>	0	0	<b>0</b>	0	0	<b>0</b>
Ovary	0	0	<b>0</b>	0	0	<b>0</b>	0	0	<b>0</b>
Pancreas	0	0	<b>0</b>	0	0	<b>0</b>	0	0	<b>0</b>
Sinonasal	21.1 (11.8, 34.7)	13.6 (8.2, 22.5)	<b>17.7 (10.2, 29.2)</b>	13 (7, 22)	7 (4, 12)	<b>20 (11, 34)</b>	46 (26, 76)	22 (12, 36)	<b>68 (38, 112)</b>
STS	0	0	<b>0</b>	0	0	<b>0</b>	0	0	<b>0</b>
Stomach	0	0	<b>0</b>	0	0	<b>0</b>	0	0	<b>0</b>
Thyroid	0.12	0.02	<b>0.05</b>	0	0	<b>0</b>	1	0	<b>1</b>
Total Based on deaths	6.6 (6.0, 7.2)	1.2 (1.0, 1.4)	<b>4.0 (3.6, 4.4)</b>	5123 (4665, 5635)	862 (758, 1019)	<b>5986 (5415, 6612)</b>			
Total Based on registrations	4.7 (3.2, 6.8)	2.0 (1.3, 2.8)	<b>3.4 (2.3, 4.8)</b>				8277 (5642, 11886)	1313 (839, 2075)	<b>9590 (6482, 13962)</b>
Total cancers in GB in ages 15+				<b>77912</b>	<b>72212</b>	<b>150124</b>	<b>175399</b>	<b>168184</b>	<b>343583</b>

NHL = Non-Hodgkin's lymphoma; NMSC = non-melanoma skin cancer; STS = soft tissue sarcoma

<sup>a</sup> AF applicable to all leukaemias

<sup>b</sup> Includes cases described as due to paraoccupational or environmental exposure to asbestos.

<sup>c</sup> Taken as equal to attributable deaths for this short survival cancer.

<sup>d</sup> Based on registrations.

Totals do not always sum across rows due to rounding error

Confidence Intervals not estimated for cancers attributed to ionizing radiation, as they are not yet available for the excess relative risk models used (UNSCEAR 2006)

### 3.2 DEATHS AND REGISTRATIONS BY CARCINOGEN AND CANCER SITE

Tables 2 and 3 give total deaths and total registrations respectively, by cancer site and for each carcinogenic agent or occupational circumstance, together with a ranking by total carcinogenic agent. 95% confidence intervals for these figures, numbers of deaths and registrations for males and females and their 95% confidence intervals are available on the HSE website, together with the attributable fractions and their 95% confidence intervals.

Asbestos contributes the most to total attributable deaths (Table 2) (larynx (3), lung (1937), mesothelioma (1937), stomach (32)), followed by silica (lung (789)), diesel engine exhaust (DEE (652)), mineral oils (bladder (131), lung (410), sinonasal (19)), shift work (breast (552), work as a painter (bladder (31), lung (246), stomach(57)), environmental tobacco smoke (ETS) encountered at work in non-smokers (lung (249)), dioxins (TCDD) (lung (187)), radon exposure from natural exposure in workplaces (lung (184)), and work as a welder (lung (152)).

Fifteen of the carcinogens contributed over 100 total cancer registrations (Table 3), the largest being asbestos exposure (mesothelioma and lung (1937), larynx (8) and stomach cancers (47)), followed in order by shift work, including flight personnel (breast (1957), mineral oils (bladder (296), lung (470), NMSC (902), sinonasal (63), solar radiation (SR) (NMSC (1541)), silica (lung (907)), diesel engine exhaust (DEE) (lung (695), bladder (106)), PAHs from coal tar and pitches (NMSC (545)), occupation as a painter (bladder (71), lung (282), stomach (5)), dioxins (lung (215), NHL (74), STS (27)), ETS (lung (284)), radon (lung (209)), occupation as a welder (lung (175), melanoma of the eye due to UV radiation (6)), tetrachloroethylene (cervix (18), NHL (17), oesophagus (130)), arsenic (lung (129)) and strong inorganic acid mists (larynx (46), lung (76)).

The results in these tables highlight the fact that many carcinogenic exposures in the workplace affect multiple cancer sites.

**Table 2** Total deaths by carcinogenic agent or occupational circumstance and cancer site

Agent	Cancer Site <sup>a</sup>												
	Bladder	Bone	Brain	Breast	Cervix	Kidney	Larynx	Leukaemia	Liver	Lung	LH	Melanoma_eye	Mesothelioma
1,3-Butadiene								0			0		
Acrylamide													
Aromatic amines	31												
Arsenic										113			
Asbestos							3			1,937			1,937
Benzene								4					
Beryllium										6			
Cadmium										8			
Chromium IV										58			
Cobalt										63			
Diesel engine exhaust	47									605			
Ethylene oxide								0					
Environmental Tobacco Smoke										249			
Flight personnel				4									
Formaldehyde								7					
Hairdressers and barbers	8												
Inorganic lead			2							36			
Ionising radiation		0						0	0	2			
Leather Dust													
Mineral oils	131									410			
Nickel										9			
Non-arsenical insecticides			9					12					
PAHs	3									4			
PAHs - Coal tars and pitches													

Agent	Cancer Site <sup>a</sup>												
	Bladder	Bone	Brain	Breast	Cervix	Kidney	Larynx	Leukaemia	Liver	Lung	LH	Melanoma_eye	Mesothelioma
Painters	31									246			
Petroleum refining			0										
Radon										184			
Rubber industry							1						
Shift work				552									
Silica										789			
Solar radiation													
Soots													
Steel foundry workers										25			
Strong inorganic-acid mists containing sulfuric acid							16			67			
TCDD (dioxins)										187			
Tetrachloroethylene					7								
Tin miners										2			
Trichloroethylene						1			2				
UV												1	
Vinyl chloride									3				
Welders										152			
Wood dust													
<b>Total deaths</b>	<b>245</b>	<b>0</b>	<b>11</b>	<b>555</b>	<b>7</b>	<b>1</b>	<b>20</b>	<b>24</b>	<b>5</b>	<b>4,749</b>	<b>0</b>	<b>1</b>	<b>1,937</b>
<b>Total deaths in GB 2005<sup>b</sup></b>	<b>4642</b>	<b>233</b>	<b>3215</b>	<b>12182</b>	<b>1036</b>	<b>3499</b>	<b>766</b>	<b>3102</b>	<b>2794</b>	<b>32,798</b>	<b>8479</b>	<b>83</b>	<b>2040</b>

NHL= non-Hodgkin's lymphoma; PAH = polycyclic aromatic hydrocarbon; TCDD = 2,3,7,8-Tetrachlorodibenzodioxin; UV = ultra violet

<sup>a</sup>Blank cells indicate that attributable cancer deaths were not estimated for this occupational exposure. Zero represents an estimate of less than 0.5.

<sup>b</sup>Deaths aged 25+ for solid tumours, aged 15-84 for haematopoietic neoplasms for men and 15-79 for haematopoietic neoplasms for women

**Table 2: Continued**

Agent	Cancer Site <sup>a</sup>											Total	Rank
	MM	Nasopharynx	NHL	NMSC	Oesophagus	Ovary	Pancreas	Sinonasal	STS	Stomach	Thyroid		
1,3-Butadiene												1	40
Acrylamide							1					1	39
Aromatic amines												31	20
Arsenic												113	12
Asbestos										32		3,909	1
Benzene												4	32
Beryllium												6	29
Cadmium												8	27
Chromium IV								7				65	14
Cobalt												63	15
Diesel engine exhaust												652	3
Ethylene oxide												0	41
Environmental Tobacco Smoke												249	7
Flight personnel												4	34
Formaldehyde		1						0				8	26
Hairdressers and barbers			5			23						36	19
Inorganic lead										16		54	17
Ionising radiation											0	3	36
Leather Dust								10				10	24
Mineral oils				7				19				566	4
Nickel								0				9	25
Non-arsenical insecticides	6		13									40	18
PAHs												7	28
PAHs - Coal tars and pitches				4								4	31
Painters										57		334	6

Agent	Cancer Site <sup>a</sup>											Total	Rank
	MM	Nasopharynx	NHL	NMSC	Oesophagus	Ovary	Pancreas	Sinonasal	STS	Stomach	Thyroid		
Petroleum refining												0	42
Radon												184	9
Rubber industry										4		5	30
Shift work												552	5
Silica												789	2
Solar radiation				12								12	23
Soots					59							59	16
Steel foundry workers												25	21
Strong inorganic-acid mists containing sulfuric acid												83	13
TCDD			31						13			231	8
Tetrachloroethylene			7		126							140	11
Tin miners												2	37
Trichloroethylene			1									4	33
UV												1	38
Vinyl chloride												3	35
Welders												152	10
Wood dust		7						12				19	22
<b>Total deaths</b>	<b>6</b>	<b>8</b>	<b>57</b>	<b>23</b>	<b>184</b>	<b>23</b>	<b>1</b>	<b>39</b>	<b>13</b>	<b>108</b>	<b>0</b>	<b>8,019</b>	
<b>Total deaths in GB 2005<sup>b</sup></b>	<b>1769</b>	<b>97</b>	<b>3281</b>	<b>501</b>	<b>7286</b>	<b>4234</b>	<b>7111</b>	<b>115</b>	<b>557</b>	<b>5515</b>	<b>337</b>	<b>150124<sup>c</sup></b>	

MM = multiple myeloma; NHL = Non-Hodgkin's lymphoma; NMSC = non-melanoma skin cancer; PAH = polycyclic aromatic hydrocarbon; STS = soft tissue sarcoma; TCDD = 2,3,7,8-Tetrachlorodibenzodioxin; UV = ultra violet

<sup>a</sup>Blank cells indicate that attributable cancer deaths were not estimated for this occupational exposure. Zero represents an estimate of less than 0.5.

<sup>b</sup>Deaths aged 25+ for solid tumours, aged 15-84 for haematopoietic neoplasms for men and 15-79 for haematopoietic neoplasms for women

<sup>c</sup>All malignant neoplasms

**Table 3** Total cancer registrations by carcinogenic agent or occupational circumstance and cancer site

Agent	Cancer Site <sup>a</sup>												
	Bladder	Bone	Brain	Breast	Cervix	Kidney	Larynx	Leukaemia	Liver	Lung	LH	Melanoma_eye	Mesothelioma
1,3-Butadiene								0			1		
Acrylamide													
Aromatic amines	66												
Arsenic										129			
Asbestos							8			2,223			1,937
Benzene								7					
Beryllium										7			
Cadmium										9			
Chromium IV										67			
Cobalt										73			
Diesel engine exhaust	106									695			
Ethylene oxide								1					
Environmental Tobacco Smoke										284			
Flight personnel				13									
Formaldehyde								12					
Hairdressers and barbers	15												
Inorganic lead			2							42			
Ionising radiation		0						1	0	2			
Leather Dust													
Mineral oils	296									470			
Nickel										10			
Non-arsenical insecticides			11					19					
PAHs	7									4			
PAHs - Coal tars and pitches													

Agent	Cancer Site <sup>a</sup>												
	Bladder	Bone	Brain	Breast	Cervix	Kidney	Larynx	Leukaemia	Liver	Lung	LH	Melanoma_eye	Mesothelioma
Painters	71									282			
Petroleum refining			0										
Radon										209			
Rubber industry							3						
Shift work				1,957									
Silica										907			
Solar radiation													
Soots													
Steel foundry workers										29			
Strong inorganic-acid mists containing sulphuric acid							46			76			
TCDD										215			
Tetrachloroethylene					18								
Tin miners										2			
Trichloroethylene						3			2				
UV												6	
Vinyl chloride									3				
Welders										175			
Wood dust													
<b>Total Attributable Registrations</b>	<b>550</b>	<b>0</b>	<b>14</b>	<b>1,969</b>	<b>18</b>	<b>3</b>	<b>56</b>	<b>40</b>	<b>5</b>	<b>5,447</b>	<b>1</b>	<b>6</b>	<b>1,937</b>
<b>Total Registrations in GB 2004<sup>b</sup></b>	<b>9,878</b>	<b>323</b>	<b>3,933</b>	<b>43,202</b>	<b>2,612</b>	<b>6,759</b>	<b>2,112</b>	<b>5,149</b>	<b>2,798</b>	<b>37,378</b>	<b>18,090</b>	<b>383</b>	<b>2,040</b>

LH = lymphohaematopoietic cancers; PAH = polycyclic aromatic hydrocarbon; TCDD = 2,3,7,8-Tetrachlorodibenzodioxin; UV = ultra violet

<sup>a</sup>Blank cells indicate that attributable cancer registrations were not estimated for this occupational exposure. Zero represents an estimate of less than 0.5.

<sup>b</sup>Registrations aged 25+ for solid tumours, aged 15-84 for haematopoietic neoplasms for men and 15-79 for haematopoietic neoplasms for women; figures for mesothelioma based on deaths.

**Table 3: Continued**

Agent	Cancer Site <sup>a</sup>											Total	Rank
	MM	Nasopharynx	NHL	NMSC	Oesophagus	Ovary	Pancreas	Sinonasal	STS	Stomach	Thyroid		
1,3-Butadiene												1	39
Acrylamide							1					1	40
Aromatic amines												66	20
Arsenic												129	14
Asbestos										47		4,216	1
Benzene												7	33
Beryllium												7	31
Cadmium												9	30
Chromium IV								22				89	16
Cobalt												73	18
Diesel engine exhaust												801	6
Ethylene oxide												1	41
Environmental Tobacco Smoke												284	10
Flight personnel												13	27
Formaldehyde		1						1				14	26
Hairdressers and barbers			14			33						63	21
Inorganic lead										23		67	19
Ionising radiation											1	4	36
Leather Dust								31				31	24
Mineral oils				902				63				1,730	3
Nickel								0				10	29
Non-arsenical insecticides	10		33									73	17
PAHs												11	28
PAHs - Coal tars and pitches				545								545	7
Painters										5		359	8

Agent	Cancer Site <sup>a</sup>											Total	Rank
	MM	Nasopharynx	NHL	NMSC	Oesophagus	Ovary	Pancreas	Sinonasal	STS	Stomach	Thyroid		
Petroleum refining												0	42
Radon												209	11
Rubber industry										1		4	35
Shift work												1,957	2
Silica												907	5
Solar radiation				1,541								1,541	4
Soots					60							60	22
Steel foundry workers												29	25
Strong inorganic-acid mists containing sulphuric acid												122	15
TCDD			74						27			316	9
Tetrachloroethylene			17		130							164	13
Tin miners												2	38
Trichloroethylene			3									7	32
UV												6	34
Vinyl chloride												3	37
Welders												175	12
Wood dust		14						39				54	23
<b>Total Attributable Registrations</b>	<b>10</b>	<b>16</b>	<b>140</b>	<b>2,928</b>	<b>188</b>	<b>33</b>	<b>1</b>	<b>133</b>	<b>27</b>	<b>158</b>	<b>1</b>	<b>13,679</b>	
<b>Total Registrations in GB 2004<sup>b</sup></b>	<b>3,006</b>	<b>189</b>	<b>8,236</b>	<b>67,220</b>	<b>7,498</b>	<b>6,197</b>	<b>7,246</b>	<b>378</b>	<b>1,063</b>	<b>7,970</b>	<b>1,519</b>	<b>339156<sup>c</sup></b>	

MM = multiple myeloma; NHL = Non-Hodgkin's lymphoma; NMSC = non-melanoma skin cancer; PAH = polycyclic aromatic hydrocarbon; STS = soft tissue sarcoma; TCDD = 2,3,7,8-Tetrachlorodibenzodioxin; UV = ultra violet

<sup>a</sup>Blank cells indicate that attributable cancer registrations were not estimated for this occupational exposure. Zero represents an estimate of less than 0.5.

<sup>b</sup>Registrations aged 25+ for solid tumours, aged 15-84 for haematopoietic neoplasms for men and 15-79 for haematopoietic neoplasms for women; figures for mesothelioma based on deaths.

<sup>c</sup>All malignant neoplasms

### **3.3 DEATHS AND REGISTRATIONS BY INDUSTRY SECTOR AND CARCINOGENIC AGENT OR OCCUPATIONAL CIRCUMSTANCE**

Tables 4 and 5 give total deaths and total registrations respectively, by industry sector and for each carcinogenic agent or occupational circumstance; a rank based on the total over all carcinogenic agents is given for industry sector. Numbers of deaths and registrations for males, females and the total are available on the HSE website, together with the respective attributable fractions.

The top ten industry sectors contributing to the total burden differs between deaths and registrations, being for deaths: construction, personal and household services (this sector includes repair trades, laundries and dry cleaning, domestic services, hairdressing and beauty), shift work, land transport, metal workers, painters and decorators in the construction industry, printing and publishing, wholesale and retail trades, mining, and manufacture of transport equipment; and for registrations: construction, shift work, metal work, personal and household services, roofers and road repairs, land transport, painters and decorators in the construction industry, mining, printing and publishing, and public administration and defence. The difference occurs because of the increased numbers of cancer registrations compared to deaths for longer survival cancers such as breast and NMSC.

Twenty one industry sectors have 100 or more total attributable registrations (Table 5). As can be seen from examination of the columns in both tables 4 and 5, the majority of industry sectors involve exposure to several carcinogens (many over 10) with construction and many of the manufacturing sectors involving potential exposure to between 15 and 20 carcinogens. In addition, the potential occurrence of several exposures in what might be thought as less traditionally exposed sectors e.g. dry cleaning, hairdressing and beauty is highlighted. There are several key exposures which give rise to substantial numbers of registrations across multiple industry sectors. Of note is the contribution of exposure to (i) asbestos, DEE, silica and solar radiation in the construction industry; (ii) asbestos, DEE, ETS (non-smokers), soots and tetrachloroethylene in personal and household services; (iii) asbestos and DEE in land transport (railway, road, pipeline); (iv) asbestos, DEE, silica and solar radiation in mining; (v) ETS (non-smokers) and solar radiation in public administration and defence; (vi) asbestos, ETS (non-smokers) and radon in the wholesale and retail trade, restaurants and hotels and (vii) dioxins, non-arsenical insecticides and solar radiation in farming.

**Table 4** Total cancer deaths by industry sector and carcinogenic agent or occupational circumstance

Industry Sector/Carcinogenic agent	1,3-Butadiene	Acrylamide	Aromatic amines	Arsenic	Asbestos	Benzene	Beryllium	Cadmium	Chromium IV	Cobalt	Diesel engine exhaust	Ethylene oxide	Environmental Tobacco Smoke	Flight personnel
Farming														
Forestry														
Horticulture														
<i><b>Total agricultural, hunting, fishing and forestry</b></i>														
Beverage industries						0			0	0	2			
Crude petroleum and natural gas production						0			0	0	4	0		
Electricity, gas and steam				1	19		0		0	0	2			
Food manufacturing									0	3	2	0		
General industry														
Iron and steel basic industries			7			0			0		0			
Manufacture of electrical machinery, apparatus, appliances, supplies				5			0	1	0	1	1			
Manufacture of fabricated metal products, (not machinery and equipment							0		20	9	2			
Manufacture of footwear									0					
Manufacture of furniture and fixture, except primary of metal				7					0	7	0			
Manufacture of glass and glass products				6			0		0	1	0			
Manufacture of industrial chemicals	0	1	0	3	63	0		1	3	5	1			
Manufacture of instruments, photographic and optical goods							0		0	2	0			
Manufacture of leather and products of leather or of its substitutes			3						0	0				
Manufacture of machinery except electrical							5		22	5	2			
Manufacture of miscellaneous products of petroleum and coal						0					0			
Manufacture of other chemical products	0	0		0	68	0			2	9	1	0		
Manufacture of other non-metallic mineral products				1					0	0	6			
Manufacture of paper and paper products	0				36				0	1	1			
Manufacture of plastic products not elsewhere classified	0		0			0			0	1	0			
Manufacture of pottery, china and earthenware									0	1				
Manufacture of rubber products	0	0	0						0	0				
Manufacture of textiles			11						0	0	1			
Manufacture of transport equipment				0	113		0		14	3	1			
Manufacture of wearing apparel, except footwear									0	1	1			
Manufacture of wood and wood and cork products, except furniture				31					0	2	2			

Industry Sector/Carcinogenic agent	1,3-Butadiene	Acrylamide	Aromatic amines	Arsenic	Asbestos	Benzene	Beryllium	Cadmium	Chromium IV	Cobalt	Diesel engine exhaust	Ethylene oxide	Environmental Tobacco Smoke	Flight personnel
Metal Workers														
Mining					173						35			
Non-ferrous metal basic industries				44		0		6	2	5	1			
Other manufacturing industries			0	0					1	0	0			
Painters (not construction)														
Petroleum refineries	0			0	37	0			0	0	0			
Printing, publishing and allied industries									0	4	0			
Tobacco manufacture											0			
Water works and supply											2			
Welders														
<b>Total manufacturing industry, mining, quarrying, electricity, gas, water</b>	<b>0</b>	<b>1</b>	<b>22</b>	<b>99</b>	<b>508</b>	<b>0</b>	<b>6</b>	<b>8</b>	<b>64</b>	<b>58</b>	<b>66</b>	<b>0</b>		
Construction				13	2,717				0	4	234		32	
Painters and decorators (construction)														
Roofers, road surfacers, Roadmen, Paviers (Construction)														
<b>Total Construction</b>				<b>13</b>	<b>2,717</b>				<b>0</b>	<b>4</b>	<b>234</b>		<b>32</b>	
Air transport						0			0	1	2		10	
Business, professional and other organisation													1	
Communication											2		6	
Education services	0		0			0							4	
Financing, insurance, real estate and business services													29	
Flight Personnel														4
Land transport					130	0			0		284		3	
Medical, dental, other health and veterinary services	0		0									0		
Personal and household services			9		454	3			1		25		19	
Public administration and defence											1		18	
Recreational and cultural services				0									8	
Research and scientific institutes	0	0	0			0						0	1	
Sanitary and similar services				1	17	0			0	0	2		3	
Services allied to transport						0			0	0	26		5	
Shift work														
Water transport						0			0		5		3	









































































## 6.0 STATISTICAL APPENDIX

### Formulae used in the estimation of AF

1. Levin's equation

$$AF = \text{Pr}(E) * (RR-1) / \{1 + \text{Pr}(E) * (RR-1)\} \quad (1)$$

where RR = relative risk, Pr(E) = proportion of the population exposed

A common denominator is used across exposure levels and industries for each exposure

2. Miettinen's equation

$$AF = \text{Pr}(E|D) * (RR-1) / RR \quad (2)$$

where Pr(E|D) = proportion of cases exposed (E = exposed, D = case)

3. Turnover equation to estimate numbers ever employed during the REP

$$N_{e(\text{REP})} = \sum_{i=a}^{i=b} l_{(\text{adj}15)_i} * n_0 / (R-15) \} \\ + \sum_{k=0}^{k=(\text{age}(u)-\text{age}(l))} \sum_{j=c+k}^{j=d+k} \{l_{(\text{adj}15)_j} * n_0 * \text{TO} / (\text{age}(u)-\text{age}(l)+1)\} \quad (3)$$

Where:

$N_{e(\text{REP})}$  = numbers ever employed in the REP

$n_0$  = numbers employed in the exposed job/industry at a mid-point in the REP

TO = staff turnover per year

R = retirement age (65 for men, 60 for women)

$l_{(\text{adj}15)_i}$  = the proportion of survivors to age i of those alive at age 15 (from GB life tables)

a to b = age range achieved by the original cohort members by the target year (2004) (65 to 100 for the solid tumour REP; 35 to 84 (men) and 35-79 (women) for the short latency REP)

c to d = age range achieved by the turnover recruited cohort members by the target year (25 to 64 for the solid tumour REP; 15 to 34 for the short latency REP)

age(u) and age(l) = upper and lower recruitment age limits (24 and 15)

The equation can be represented as a single factor acting as a multiplier for  $n_0$ , calculated by setting  $n_0$  to 1 in the above equation, so that the factor varies only with TO see Table A1 below.

4. Equation to estimate the proportion of the population exposed

$$\text{Pr}(E) = N_{e(\text{REP})} / N_{p(\text{REP})} \quad (4)$$

where  $N_{p(\text{REP})}$  = numbers ever of working age during the REP from population estimates for the relevant age cohorts in the target year

5. Equation for combining AFs where exposed populations overlap but are independent and risk estimates are assumed to be multiplicative:

$$AF_{\text{overall}} = 1 - \prod_k (1 - AF_k) \text{ for the } k \text{ exposures in the set} \quad (5)$$

**Table A1** Employment level adjustment and turnover factors used in the calculation of AF

		<b>Main Industry Sector</b>	<b>Adjustment factor for change in employment levels*</b>	<b>Turnover per year</b>
Men	A-B	Agriculture, hunting and forestry; fishing	1	7%
	C-E	Mining and quarrying, electricity, gas and water; manufacturing industry	1.4	9%
	F	Construction	1	12%
	G-Q	Service industries	0.9	11%
		Total	1	10%
Women	A-B	Agriculture, hunting and forestry; fishing	0.75	10%
	C-E	Mining and quarrying, electricity, gas and water; manufacturing industry	1.5	14%
	F	Construction	0.67	15%
	G-Q	Service industries	0.8	15%
		Total	0.9	14%

\* Applied to CAREX data for the solid tumour REP only. Exposed numbers are obtained for a mid-point year in the REP where national employment data sources have been used (the LFS or CoE).





# The burden of occupational cancer in Great Britain

## Overview report

The aim of this project was to produce an updated estimate of the current burden of occupational cancer specifically for Great Britain. The primary measure of the burden of cancer used in this project was the attributable fraction (AF) ie the proportion of cases that would not have occurred in the absence of exposure; this was then used to estimate the attributable numbers. This involved obtaining data on the risk of the disease due to the exposure of interest, taking into account confounding factors and overlapping exposures, and the proportion of the target population exposed over the period in which relevant exposure occurred. Estimation was carried out for occupational exposures classified by the International Agency for Research on Cancer (IARC) as group 1 (established) and 2A carcinogens (probable).

5.3% (8023) cancer deaths were attributable to occupation in 2005 (men: 8.2% (6366); women 2.3% (1657)). Attributable estimates for total cancer registrations are 13694 (4.0%); and for men: 10074 (5.7%) and women 3620 (2.1%). Occupational attributable fractions are over 2% for mesothelioma, sinonasal, lung, nasopharynx, breast, non-melanoma skin cancer, bladder, oesophagus, soft tissue sarcoma and stomach cancers. Asbestos, shift work, mineral oils, solar radiation, silica, diesel engine exhaust, coal tars and pitches, occupation as a painter or welder, dioxins, environmental tobacco smoke, radon, tetrachloroethylene, arsenic and strong inorganic mists each contribute 100+ registrations. Industries/occupations with high cancer registrations include construction, metalworking, personal/household services, mining, land transport, printing/publishing, retail/hotels/restaurants, public administration/defence, farming and several manufacturing sectors. 56% of cancer registrations in men are attributable to work in the construction industry (mainly mesotheliomas, lung, bladder and non-melanoma skin cancers) and 54% of cancer registrations in women are attributable to shift work (breast cancer).

This project is the first to quantify in detail the burden of cancer due to occupation specifically for GB. There are several sources of uncertainty in the estimates, including exclusion of other potential carcinogenic agents, inaccurate or approximate data and methodological issues. On balance, the estimates are likely to be a conservative estimate of the total attributable burden. Forthcoming reports will present the results for; estimates of Disability-Adjusted Life Years; methods to predict future estimates of the occupational cancers with examples based on important hazards; and the results of sensitivity analysis of these estimates to sources of uncertainty and bias.

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