

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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Lesley Rushton¹, Sanjeev Bagga², Ruth Bevan², Terry P Brown³, John W Cherrie⁴, Philip Holmes², Sally J Hutchings¹, Lea Fortunato¹, Rebecca Slack², Martie Van Tongeren³, Charlotte Young³

1 Imperial College London Department of Public Health and Epidemiology Faculty of Medicine St Mary's Campus, Norfolk Place London W2 3PG

2 Institute of Environment and Health Cranfield Health Cranfield University Cranfield MK43 0AL 3 Health and Safety Laboratory Mathematical Sciences Unit Harpur Hill Buxton Derbyshire SK17 9JN

4 Institute of Occupational Medicine Research Avenue North Riccarton Edinburgh EH14 4AP

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 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 nonoccupational 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 industrybased 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.

Cancer Site	Attı (95%	Attributable Fraction (%) Attributable Numbers (95% Confidence Interval) (95% Confidence Interval)								
					Deaths (2005)			Registrations (200	4)	
	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 ^a	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) ^b	82.5 (75.0, 90.0) ^b	94.9 (93.0, 96.9) ^b	1699 (1681, 1717)	238 (216, 260)	1937 (1898, 1976)	1699 (1681, 1717) [°]	238 (216, 260) ^c	1937 (1898, 1976) [°]	
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)	

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

Cancer Site	Attr (95%	ibutable Fractior 6 Confidence Inte	n (%) erval)			Attributab (95% Confid	le Numbers lence Interval)		
					Deaths (2005)			Registrations (200	4)
	Male	Female	Total (Based on Deaths)	Male	Female	Total	Male	Female	Total
NMSC ^d	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	8.2 (7.2, 9.9)	2.3 (1.7, 3.2)	5.3 (4.6, 6.6)	6362 (5641, 7690)	1657 (1249, 2289)	8019 (6891, 9983)			
Total Based on registrations	5.7 (3.9, 8.4)	2.1 (1.4, 3.2)	4.0 (2.7, 5.9)				10063 (6941 14822)	3616 (2370, 5413)	13679 (9310, 20235)
Total cancers in GB in ages 15+				77912	72212	150124	175399	168184	343583

 OD in ages 151
 72212

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

 ^a AF applicable to all leukaemias

 ^b Includes cases described as due to paraoccupational or environmental exposure to asbestos.

 ^c Taken as equal to attributable deaths for this short survival cancer.

 ^d 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	Atti (95%	ributable Fraction % Confidence Inte	(%) rval)	Attributable Numbers (95% Confidence Interval)									
					Deaths (2005)	1	R	egistrations (20	04)				
	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)	0.7 (0.6,2.8)	24 (20, 91)	10 (9, 39)	34 (29, 130)	55 (47, 211)	18 (16, 70)	73 (63, 280)				
Bone	0	0	0	0	0	0	0	0	0				
Brain	0	0	0	0	0	0	0	0	0				
Breast		0	0		0	0		0	0				
Cervix	0	0	0	0	0	0	0	0	0				
Kidney	0	0	0	0	0	0	0	0	0				
Larynx	2.3 (0.8,5.1)	1.5 (0.5, 3.4)	2.1 (0.8, 4.8)	14 (5, 31)	2 (1, 5)	16 (6, 37)	40 (15, 89)	6 (2, 12)	46 (17, 102)				
Leukaemia ^a	0.1 (0, 2.0)	0.2 (0.1, 3.9)	0.2 (0, 2.6)	3 (0, 40)	2 (0, 36)	5 (1, 75)	5 (1, 70)	4 (0, 55)	8 (1, 124)				
Liver	0.2 (0.1,0.3)	0.1 (0, 0.1)	0.1 (0.1, 0.2)	2 (1, 4)	1 (0, 2)	3 (1, 6)	2 (1, 4)	1 (0, 2)	3 (2, 6)				
Lung	17.6 (15.5, 19.4)	4.4 (3.5, 5.4)	12.0 (10.2, 13.9)	3347 (2945,3687)	599 (527,660)	3946 (3472,4346)	3853 (3390,4244)	673 (592, 741)	4526 (3982, 4985)				
Lympho- haematopoietic	0	0	0	0	0	0	0	0	0				
Melanoma (eye)	0	0	0	0	0	0	0	0	0				
Mesothelioma	97.0 (96.0, 98.0) ^b	82.5 (75.0, 90.0) ^b	94.9 (93.0, 96.9) ^b	1699 (1681, 1717)	238 (216, 260)	1937 (1898, 1976)	1699 (1681, 1717) ^c	238 (216, 260) °	1937 (1898, 1976) ^c				
Multiple Myeloma	0	0	0	0	0	0	0	0	0				
Nasopharynx	0	0	0	0	0	0	0	0	0				
NHL	0	0	0	0	0	0	0	0	0				

Cancer Site	Attr (95%	ibutable Fraction 6 Confidence Inte	rval)			Attributa (95% Confi	ble Numbers dence Interval)		
					Deaths (2005)		R	egistrations (20	04)
	Male	Female	Total (Based on Deaths)	Male	Female	Total	Male	Female	Total
NMSC ^d	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	0	0	0	0	0	0	0	0	0
Ovary	0	0	0	0	0	0	0	0	0
Pancreas	0	0	0	0	0	0	0	0	0
Sinonasal	21.1 (11.8, 34.7)	13.6 (8.2, 22.5)	17.7 (10.2, 29.2)	13 (7, 22)	7 (4, 12)	20 (11, 34)	46 (26, 76)	22 (12, 36)	68 (38, 112)
STS	0	0	0	0	0	0	0	0	0
Stomach	0	0	0	0	0	0	0	0	0
Thyroid	0.12	0.02	0.05	0	0	0	1	0	1
Total Based on deaths	6.6 (6.0, 7.2)	1.2 (1.0, 1.4)	4.0 (3.6, 4.4)	5123 (4665, 5635)	862 (758, 1019)	5986 (5415, 6612)			
Total Based on registrations	4.7 (3.2, 6.8)	2.0 (1.3, 2.8)	3.4 (2.3, 4.8)				8277 (5642, 11886)	1313 (839, 2075)	9590 (6482, 13962)
Total cancers in GB in ages 15+				77912	72212	150124	175399	168184	343583

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

^a AF applicable to all leukaemias ^b Includes cases described as due to paraoccupational or environmental exposure to asbestos. ^c Taken as equal to attributable deaths for this short survival cancer.

^d 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.

							Cano	cer Site ^a					
Agent	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													

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

							Cano	cer Site ^a					
Agent	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													
Total deaths	245	0	11	555	7	1	20	24	5	4,749	0	1	1,937
Total deaths in GB 2005 ^b	4642	233	3215	12182	1036	3499	766	3102	2794	32,798	8479	83	2040

NHL= non-Hodgkin's lymphoma; PAH = polycyclic aromatic hydrocarbon; TCDD = 2,3,7,8-Tetrachlorodibenzodioxin; UV = ultra violet ^aBlank cells indicate that attributable cancer deaths were not estimated for this occupational exposure. Zero represents an estimate of less than 0.5. ^bDeaths aged 25+ for solid tumours, aged 15-84 for haematopoietic neoplasms for men and 15-79 for haematopoietic neoplasms for women

Table 2: Continue

						Cance	r Site ^a						
Agent	MM	Nasopharynx	NHL	NMSC	Oesophagus	Ovary	Pancreas	Sinonasal	STS	Stomach	Thyroid	Total	Rank
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

						Cance	r Site ^a						
Agent	MM	Nasopharynx	NHL	NMSC	Oesophagus	Ovary	Pancreas	Sinonasal	STS	Stomach	Thyroid	Total	Rank
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
Total deaths	6	8	57	23	184	23	1	39	13	108	0	8,019	
Total deaths in GB 2005 ^b	1769	97	3281	501	7286	4234	7111	115	557	5515	337	150124 ^c	

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

^aBlank cells indicate that attributable cancer deaths were not estimated for this occupational exposure. Zero represents an estimate of less than 0.5.

^bDeaths aged 25+ for solid tumours, aged 15-84 for haematopoietic neoplasms for men and 15-79 for haematopoietic neoplasms for women

^cAll malignant neoplasms

							Cance	r Site ^a					
Agent	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													

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

							Cance	r Site ^a					
Agent	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													
Total Attributable Registrations	550	0	14	1,969	18	3	56	40	5	5,447	1	6	1,937
Total Registrations in GB 2004 ^b	9,878	323	3,933	43,202	2,612	6,759	2,112	5,149	2,798	37,378	18,090	383	2,040

LH = lymphohaematopoietic cancers; PAH = polycyclic aromatic hydrocarbon; TCDD = 2,3,7,8-Tetrachlorodibenzodioxin; UV = ultra violet ^aBlank cells indicate that attributable cancer registrations were not estimated for this occupational exposure. Zero represents an estimate of less than 0.5. ^bRegistrations 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: Continue	ed
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	Cancer Site ^a													
Agent	MM	Nasopharynx	NHL	NMSC	Oesophagus	Ovary	Pancreas	Sinonasal	STS	Stomach	Thyroid	Total	Rank	
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	

	Cancer Site ^a													
Agent	MM	Nasopharynx	NHL	NMSC	Oesophagus	Ovary	Pancreas	Sinonasal	STS	Stomach	Thyroid	Total	Rank	
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	
Total Attributable Registrations	10	16	140	2,928	188	33	1	133	27	158	1	13,679		
Total Registrations in GB 2004 ^b	3,006	189	8,236	67,220	7,498	6,197	7,246	378	1,063	7,970	1,519	339156 ^c		

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

^aBlank cells indicate that attributable cancer registrations were not estimated for this occupational exposure. Zero represents an estimate of less than 0.5.

^bRegistrations 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.

^cAll 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 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													a	
	diene	de					_	_	۳ IV		igine		nent: o	-
	utac	ami	latic es	Jic	stos	ene	lium	nium	miuı	It	el en ust	ene	onn acce	t onne
	3-B	cryl	min	Isei	sbe	enz	eryl	adn	hro	oba	iese xha	thyl xide	nvir Tob mol	ligh
	7	◄	A aı	A	A	В	В	ပ	C	C	D 6)	ШÔ	ш ,	шă
Farming														
Forestry														·
Horticulture														·
Total agricultural, hunting, fishing and forestry														·
Beverage industries						0			0	0	2			<u> </u>
Crude petroleum and natural gas production						0			0	0	4	0		<u> </u>
Electricity, gas and steam				1	19		0		0	0	2			ļ
Food manufacturing									0	3	2	0		<u> </u>
General industry														<u> </u>
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				Ŭ			Ŭ		0	1	1			
Manufacture of wood and wood and cork products, except furniture				31					0	2	2			

Industry Sector/Carcinogenic agent	0										•		a	
	tadiene	mide	ltic s	c	tos	ne	шn	m	ium IV		engine st	ne	nment cco	Inel
	3-Bu	cryla	roma nine:	rseni	sbes	enze	erylli	admi	hrom	obalt	iesel khau:	thyle xide	nviro Foba	light ersor
	1,	Ā	A ar	A	A	ä	ñ	Ö	Ö	Ŭ	e D	ю Ш	ΞΞø	P(
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														
Total manufacturing industry, mining, quarrying, electricity, gas, water	0	1	22	99	508	0	6	8	64	58	66	0		
Construction				13	2,717				0	4	234		32	
Painters and decorators (construction)														
Roofers, road surfacers, Roadmen, Paviors (Construction)														
Total Construction				13	2,717				0	4	234		32	
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	

Industry Sector/Carcinogenic agent	1,3-Butadiene	Acrylamide	Aromatic amines	Arsenic	Asbestos	Benzene	Beryllium	Cadmium	Chromium IV	Cobalt	Diesel engine exhaust	Ethylene oxide	Environmenta I Tobacco Smoke	Flight personnel
Welfare institutions													5	
Wholesale and retail trade and restaurants and hotels					83	1					5		104	
Total Service industries	0	0	9	1	684	4			1	2	352	0	218	4
TOTAL	1	1	31	113	3,909	4	6	8	65	63	652	0	249	4

Table 4: Continued

Industry Sector/Carcinogenic agent	0		_						S					
	Formaldehyde	Hairdressers and barbers	Inorganic lead	lonising radiation	Leather Dust	Mineral oils	Nickel	Non-arsenical insecticides	Polycyclic Aromatic Hvdrocarbons	PAHs - Coal tars and pitches	Painters	Petroleum refining	Radon	Rubber industry
Farming								28					0	
Forestry								1					0	
Horticulture								10						
Total agricultural, hunting, fishing and forestry								39					0	
Beverage industries													1	
Crude petroleum and natural gas production									0					
Electricity, gas and steam				1					0				1	
Food manufacturing								0	0				5	
General industry				0										
Iron and steel basic industries	0		1			0			2	0			1	
Manufacture of electrical machinery, apparatus, appliances, supplies			8										6	
Manufacture of fabricated metal products, (not machinery and equipment	0						4		0				3	
Manufacture of footwear					7				0				0	
Manufacture of furniture and fixture, except primary of metal	2												2	
Manufacture of glass and glass products	0												0	
Manufacture of industrial chemicals	0		2					1	1				1	
Manufacture of instruments, photographic and optical goods						46							1	
Manufacture of leather and products of leather or of its substitutes					3								0	
Manufacture of machinery except electrical	0			0		0			0				8	
Manufacture of miscellaneous products of petroleum and coal									0				0	
Manufacture of other chemical products	0		3										2	
Manufacture of other non-metallic mineral products	0								2				1	
Manufacture of paper and paper products									0				1	
Manufacture of plastic products not elsewhere classified	0		8										2	
Manufacture of pottery, china and earthenware								1	0				1	
Manufacture of rubber products			1						0				1	5
Manufacture of textiles	1												2	
Manufacture of transport equipment						0	2		0				5	
Manufacture of wearing apparel, except footwear	3								0				2	

Industry Sector/Carcinogenic agent									Ś					
	hyde	sers ers	: leac		Dust	ils		nical des	c bons	oal		۶		
	alde	res	anic	ing tion	ler D	ral o	-	arse	sycli atic	s - C and es	ers	leur ng	Ę	er stry
	orm	aird nd b	lorg	adia	eath	line	icke	on-i Isec	olyc rom vdre	AHs ars a itch	aint	etro	ado	qqn
	Ű.	а	L	ol S	Ľ	Σ	z	⊒. Z	d ∢ ĭ	e ta e	Р	4 2	R	R
Manufacture of wood and wood and cork products, except furniture	2								0				1	
Metal Workers						283								
Mining			0	0			0		0				0	
Non-ferrous metal basic industries	0		6				3		2				1	
Other manufacturing industries													1	
Painters (not construction)											79			
Petroleum refineries									0			0	0	
Printing, publishing and allied industries			1			234							4	
Tobacco manufacture									0				0	
Water works and supply													0	
Welders														
Total manufacturing industry, mining, quarrying, electricity, gas,														
water	7		29	2	10	564	9	1	7	0	79	0	55	5
Construction	0		25						0				8	
Painters and decorators (construction)											254			
Roofers, road surfacers, Roadmen, Paviors (Construction)										4				
Total Construction	0		25						0	4	254		8	
Air transport													1	
Business, professional and other organisation													1	
Communication													2	
Education services	0												12	
Financing, insurance, real estate and business services													23	
Flight Personnel				1										
Land transport				0					0				3	
Medical, dental, other health and veterinary services	0			0									12	
Personal and household services	0	36				2			0				6	
Public administration and defence									0				11	
Recreational and cultural services													4	
Research and scientific institutes	0			0									1	
Sanitary and similar services				0					0				2	
Services allied to transport		1							0				1	
Industry Sector/Carcinogenic agent	Formaldehyde	Hairdressers and barbers	Inorganic lead	lonising radiation	Leather Dust	Mineral oils	Nickel	Non-arsenical insecticides	Polycyclic Aromatic Hvdrocarbonss	PAHs - Coal tars and pitches	Painters	Petroleum refining	Radon	Rubber industry
---	--------------	-----------------------------	----------------	-----------------------	--------------	--------------	--------	-------------------------------	---	------------------------------------	----------	-----------------------	-------	--------------------
Shift work														
Water transport									0				0	
Welfare institutions													5	
Wholesale and retail trade and restaurants and hotels									0				37	
Total Service industries	0	36		1		2			0				121	
TOTAL	8	36	54	3	10	566	9	40	7	4	334	0	184	5

Industry Sector/Carcinogenic Agent								e		_						
	hift work	ilica	olar adiation	oots	teel oundry orkers	iorganic- cid mists ontaining	CDD lioxins)	etrachloro Iylene	in miners	richloroett ene	ltra Violet	inyl hloride	/elders	/ood dust	verall	ank
	S	S	S R	S	ς ς s	ŭ ä Ξ.	Ĕ O	ţ	T	ΓŅ	, D	ר <	N	\$	0	R
Farming			1				35								65	19
Forestry			0				1							0	2	55
Horticulture							11								21	34
Total agricultural, hunting, fishing and forestry			1				47							0	88	<u> </u>
Beverage industries								0						0	4	53
Crude petroleum and natural gas production						0		0						0	4	51
Electricity, gas and steam		5	0					2						0	33	30
Food manufacturing			0					2				0		0	12	39
General industry															0	59
Iron and steel basic industries			0		25	1	46	1						0	84	16
Manufacture of electrical machinery, apparatus, appliances, supplies						10		6		1				0	39	27
Manufacture of fabricated metal products, (not machinery and																
equipment		12	0			12		11		1				0	75	18
Manufacture of footwear														0	7	47
Manufacture of furniture and fixture, except primary of metal														5	22	33
Manufacture of glass and glass products		11	0				31	0						0	49	26
Manufacture of industrial chemicals		1				11	8					1		0	103	14
Manufacture of instruments, photographic and optical goods												0		0	49	25
Manufacture of leather and products of leather or of its substitutes						2		0						0	8	46
Manufacture of machinery except electrical		25				9		16		1				0	91	15
Manufacture of miscellaneous products of petroleum and coal		0													1	58
Manufacture of other chemical products		9				14						1		0	107	13
Manufacture of other non-metallic mineral products		37	0				14							0	61	20
Manufacture of paper and paper products						7	6	2						0	53	22
Manufacture of plastic products not elsewhere classified												1		0	11	41
Manufacture of pottery, china and earthenware		33	0			0	25	0							60	21
Manufacture of rubber products														0	7	48
Manufacture of textiles								2						0	17	35
Manufacture of transport equipment	1	10	0			8		5		1				0	162	10
Manufacture of wearing apparel, except footwear	1		0					3		0		0		0	10	43
Manufacture of wood and wood and cork products, except furniture			0				11				1	-		3	52	24

Industry Sector/Carcinogenic Agent								е		~						
	Shift work	Silica	Solar Radiation	Soots	Steel foundry workers	inorganic- acid mists containing	TCDD (dioxins)	Tetrachloro thylene	Tin miners	Trichloroeth ylene	Ultra Violet	Vinyl chloride	Welders	Wood dust	Overall	Rank
Metal Workers															283	5
Mining		26	0						2						235	9
Non-ferrous metal basic industries		4	0			9	38	0				0		0	121	12
Other manufacturing industries		2												0	4	52
Painters (not construction)															79	17
Petroleum refineries			0									0		0	38	28
Printing, publishing and allied industries			0					2						0	245	7
Tobacco manufacture								0						0	0	60
Water works and supply			0					0							3	54
Welders											1		152		153	11
Total manufacturing industry, mining, quarrying, electricity, gas, water		175	1		25	83	179	52	2	3	1	3	152	8	2,231	
Construction		614	7					10						10	3,605	1
Painters and decorators (construction)															254	6
Roofers, road surfacers, Roadmen, Paviors (Construction)															4	50
Total Construction		614	7					10						10	3,843	
Air transport						0		1				0		0	15	37
Business, professional and other organisation			0												2	57
Communication			0					0						0	11	42
Education services								0				0		0	16	36
Financing, insurance, real estate and business services			0												52	23
Flight Personnel															4	49
Land transport			0					3						0	423	4
Medical, dental, other health and veterinary services			0												13	38
Personal and household services			0	59				73		1					686	2
Public administration and defence			2												31	31
Recreational and cultural services			0												12	40
Research and scientific institutes			0					0				0			2	56
Sanitary and similar services			0											0	25	32
Services allied to transport			0					0				0		0	33	29
Shift work	552														552	3
Water transport			0					0				0		0	9	45

Industry Sector/Carcinogenic Agent	Shift work	Silica	Solar Radiation	Soots	Steel foundry workers	inorganic- acid mists containing	TCDD (dioxins)	Tetrachloroe thylene	Tin miners	Trichloroeth ylene	Ultra Violet	Vinyl chloride	Welders	Wood dust	Overall	Rank
Welfare institutions			0												10	44
Wholesale and retail trade and restaurants and hotels			0				6								235	8
Total Service industries	552		3	59		0	6	78		1		0		0	2,120	
TOTAL	552	789	12	59	25	83	231	140	2	4	1	3	152	19	8,019	

Table 5 Total cancer registrations by industry sector and carcinogenic agent or occupational circumstance

Industry Sector/Carcinogenic agent														1
	iene	amide	atic	ic	stos	ene	ium	ium	nium	÷	e ⊓ st	ene		nnel
	1,3- Butad	Acryl	Aroma	Arsen	Asbes	Benze	Beryll	Cadm	Chron V	Cobal	Diese engin exhau	Ethyl∉ oxide	ETS	Flight
Farming		-		-	-									
Forestry														
Horticulture														
Total agricultural, hunting, fishing and forestry														1
Beverage industries						0			0	0	3			
Crude petroleum and natural gas production						0			0	0	5	0		1
Electricity, gas and steam				1	21		0		0	0	2			1
Food manufacturing									0	4	2	0		
General industry														
Iron and steel basic industries			16			0			0		0			
Manufacture of electrical machinery, apparatus, appliances,							_							
supplies				6			0	1	1	1	1		<u> </u>	
equipment							0		26	11	2			
Manufacture of footwear									0					1
Manufacture of furniture and fixture, except primary of metal				8					0	7	0			
Manufacture of glass and glass products				7			0		0	1	0			
Manufacture of industrial chemicals	0	1	0	3	68	0		1	4	6	1			
Manufacture of instruments, photographic and optical goods							0		0	2	0			
Manufacture of leather and products of leather or of its substitutes			8						0	0				
Manufacture of machinery except electrical							6		28	5	2			
Manufacture of miscellaneous products of petroleum and coal						0					0			
Manufacture of other chemical products	0	0		0	73	0			2	10	1	0		
Manufacture of other non-metallic mineral products				1					0	0	7			
Manufacture of paper and paper products	0				39				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	1	0	0						0	0				
Manufacture of textiles			23						0	0	1			
Manufacture of transport equipment				0	121		0		18	4	2			
Manufacture of wearing apparel, except footwear									0	1	1			

Industry Sector/Carcinogenic agent														
	1,3- Butadiene	Acrylamide	Aromatic amines	Arsenic	Asbestos	Benzene	Beryllium	Cadmium	Chromium IV	Cobalt	Diesel engine exhaust	Ethylene oxide	ETS	Flight personnel
Manufacture of wood and wood and cork products, except furniture				35					0	2	2			
Metal Workers														
Mining					197						43			
Non-ferrous metal basic industries				50		0		6	3	6	2			
Other manufacturing industries			0	0					1	0	0			
Painters (not construction)														
Petroleum refineries	0			0	40	0			0	0	0			
Printing, publishing and allied industries									0	4	0			
Tobacco manufacture											0			
Water works and supply											2			
Welders														
Total manufacturing industry, mining, quarrying, electricity, gas, water	1	1	48	113	558	0	7	9	86	67	80	0		
Construction				15	2,921				0	4	290		36	
Painters and decorators (construction)														
Roofers, road surfacers, roadmen, paviors (Construction)														
Total Construction				15	2,921				0	4	290		36	
Air transport						0			0	2	3		11	
Business, professional and other organisation													1	
Communication											3		7	
Education services	0		0			0							4	
Financing, insurance, real estate and business services													33	
Flight Personnel														13
Land transport					140	1			0		350		3	
Medical, dental, other health and veterinary services	0		0									0		
Personal and household services			18		489	5			2		29		22	
Public administration and defence											1		20	
Recreational and cultural services				0									9	
Research and scientific institutes	0	0	0			0						0	1	
Sanitary and similar services				1	18	0			0	0	2		3	
Services allied to transport						0			0	0	33		6	
Shift work														

Industry Sector/Carcinogenic agent	1,3- Butadiene	Acrylamide	Aromatic amines	Arsenic	Asbestos	Benzene	Beryllium	Cadmium	Chromium IV	Cobalt	Diesel engine exhaust	Ethylene oxide	ETS	Flight personnel
Water transport						0			0		6		4	
Welfare institutions													5	
Wholesale and retail trade and restaurants and hotels					90	1					6		119	
Total Service industries	0	0	18	1	736	7			3	2	431	0	248	13
TOTAL	1	1	66	129	4,216	7	7	9	89	73	802	1	284	13

Table 5: Continued

Industry Sector/Carcinogenic agent														
	yde	s's	ead		Ist	s		ical		al				
	deh	sse rber	lic	n r	r Du	oil		seni		с С С	s	<u>۾</u>		. א
	nal	dre bai	gan	sinç atio	the	eral	e	-ars ectic	s	ls - anc hes	lter	ole	uo	ber ustr
	For	Hair and	Inor	loni radi	Lea	Min	Nic	Non inse	PAF	PAF tars pitc	Pair	Petr refir	Rad	Rub indu
Farming								51					1	
Forestry								2					0	
Horticulture								19						
Total agricultural, hunting, fishing and forestry								72					1	
Beverage industries													1	
Crude petroleum and natural gas production									0					
Electricity, gas and steam				2					0				2	
Food manufacturing								0	0				6	
General industry				0										
Iron and steel basic industries	0		2			0			3	4			1	
Manufacture of electrical machinery, apparatus, appliances,														
supplies			10										7	
equipment	0						5		0				4	
Manufacture of footwear					22				0				1	
Manufacture of furniture and fixture, except primary of metal	3												2	
Manufacture of glass and glass products	0												0	
Manufacture of industrial chemicals	0		2					1	2				2	
Manufacture of instruments, photographic and optical goods						203							1	
Manufacture of leather and products of leather or of its substitutes					10								0	
Manufacture of machinery except electrical	0			0		0			0				9	
Manufacture of miscellaneous products of petroleum and coal									0				0	
Manufacture of other chemical products	0		3										2	
Manufacture of other non-metallic mineral products	0								3				1	
Manufacture of paper and paper products									0				2	
Manufacture of plastic products not elsewhere classified	0		9										2	
Manufacture of pottery, china and earthenware									0				1	
Manufacture of rubber products			1						0				1	9
Manufacture of textiles	1												3	
Manufacture of transport equipment						0	2		0				5	
Manufacture of wearing apparel, except footwear	5								0				3	

Industry Sector/Carcinogenic agent	0		-											
	ehyde	sers ers	c leac	_	Dust	oils		enical des		toal		ε		
	nald	dres barb	gani	sing atior	ther	eral (kel	-arse	s	ls - C and hes	ters	oleu ning	uo	ber ustry
	For	Hair and	Inor	loni radi	Lea	Min	Nicł	Non inse	PAF	PAF tars pitc	Pair	Petr refir	Rad	Rub indu
Manufacture of wood and wood and cork products, except furniture	3								0				2	
Metal Workers						1,250								
Mining			0	0			0		0				0	
Non-ferrous metal basic industries	0		8				3		3				1	
Other manufacturing industries													1	
Painters (not construction)											102			
Petroleum refineries									0			0	0	
Printing, publishing and allied industries			1			270							4	
Tobacco manufacture									0				0	
Water works and supply													0	
Welders														
Total manufacturing industry, mining, quarrying, electricity, gas,	13		36	2	32	1,723	10	2	11	4	102	0	62	9
Construction	0		21						0				0	
Painters and decorators (construction)	0		51						0		225		9	
Roofers road surfacers Roadmen Payiors (Construction)											333			
Total Construction	0		21						0	542	225		0	
Air transport	U		51						U	342	333		9	
Business professional and other organisation													1	
Communication													2	
Education services	0												14	
Financing, insurance, real estate and business services	Ŭ												26	
Flight Personnel				1									20	
Land transport				0					0				4	
Medical, dental, other health and veterinary services	1			0									14	
Personal and household services	0	63				7			0				6	
Public administration and defence									0				12	
Recreational and cultural services													4	
Research and scientific institutes	0			0									1	
Sanitary and similar services				0					0				2	
Services allied to transport									0				1	

Industry Sector/Carcinogenic agent	Formaldehyde	Hairdressers and barbers	Inorganic lead	lonising radiation	Leather Dust	Mineral oils	Nickel	Non-arsenical insecticides	PAHs	PAHs - Coal tars and pitches	Painters	Petroleum refining	Radon	Rubber industry
Shift work														
Water transport									0				1	
Welfare institutions													6	
Wholesale and retail trade and restaurants and hotels									0				42	
Total Service industries	1	63		1		7			0				137	
TOTAL	14	63	67	4	32	1,730	10	73	11	545	437	0	209	9

Table 5: Continued

Industry Sector/carcinogenic agent								Θ		-						
	Shift work	Silica	Solar Radiation	Soots	Steel foundry workers	inorganic- acid mists containing	TCDD	Tetrachloro thylene	Tin miners	Trichloroeth ylene	۲ N	Vinyl chloride	Welders	Wood dust	Overall	Rank
Farming			128				41								220	12
Forestry			7				1							1	11	50
Horticulture							13								31	36
Total agricultural, hunting, fishing and forestry			135				55							1	263	
Beverage industries								0						0	4	55
Crude petroleum and natural gas production						0		0						0	5	53
Electricity, gas and steam		6	53					3						0	89	25
Food manufacturing			1					2				0		0	15	45
General industry															0	59
Iron and steel basic industries			0		29	3	75	1						0	135	17
Manufacture of electrical machinery, apparatus, appliances, supplies						15		7		1				0	49	32
Manufacture of fabricated metal products, (not machinery and equipment		14	1			17		13		1				0	94	24
Manufacture of footwear														0	23	39
Manufacture of furniture and fixture, except primary of metal			1											14	34	35
Manufacture of glass and glass products		12					43	0						0	64	29
Manufacture of industrial chemicals		1				16	11					1		0	121	19
Manufacture of instruments, photographic and optical goods												0		0	206	13
Manufacture of leather and products of leather or of its substitutes						2		0						0	20	40
Manufacture of machinery except electrical		28				13		18		2				0	111	20
Manufacture of miscellaneous products of petroleum and coal		1													1	58
Manufacture of other chemical products		10				20						1		0	123	18
Manufacture of other non-metallic mineral products		43	1				19							0	75	26
Manufacture of paper and paper products						9	7	2						0	61	31
Manufacture of plastic products not elsewhere classified												1		0	14	46
Manufacture of pottery, china and earthenware		38	23			0	35	0							98	22
Manufacture of rubber products														0	12	49
Manufacture of textiles								3						0	31	37
Manufacture of transport equipment		11	5			12		6	1	1				0	188	14
Manufacture of wearing apparel, except footwear			1					3	1	0		0		0	13	48
Manufacture of wood and wood and cork products, except furniture			2				14							8	69	28

Industry Sector/carcinogenic agent								е		<u>ر</u>						
	Shift work	Silica	Solar Radiation	Soots	Steel foundry workers	inorganic- acid mists containing	тсрр	Tetrachloro thylene	Tin miners	Trichloroetl ylene	١٧	Vinyl chloride	Welders	Wood dust	Overall	Rank
Metal Workers															1,250	3
Mining		29	31						2						302	8
Non-ferrous metal basic industries		4	9			14	50	1				0		0	159	16
Other manufacturing industries		2												0	5	54
Painters (not construction)															102	21
Petroleum refineries			7									0		0	48	33
Printing, publishing and allied industries			3					2						0	286	9
Tobacco manufacture								0						0	0	60
Water works and supply			26					0							29	38
Welders											7		175		182	15
Total manufacturing industry, mining, quarrying, electricity, gas, water		200	163		29	122	254	60	2	5	7	3	175	24	3,944	
Construction		707	841					11						30	4,816	1
Painters and decorators (construction)															334	7
Roofers, road surfacers, Roadmen, Paviors (Construction)															541	5
Total Construction		707	841					11						30	5,656	
Air transport						0		1				0		0	18	42
Business, professional and other organisation			1												3	56
Communication			5					0						0	17	43
Education services								0				0		0	18	41
Financing, insurance, real estate and business services			3												63	30
Flight Personnel															14	47
Land transport			6					3						0	505	6
Medical, dental, other health and veterinary services			1												16	44
Personal and household services			14	60				89		2					804	4
Public administration and defence			240												273	10
Recreational and cultural services			55												69	27
Research and scientific institutes			1					0				0			3	57
Sanitary and similar services			68											0	95	23
Services allied to transport			3					0				0		0	43	34
Shift work	1,957														1,957	2
Water transport			1					0				0		0	11	52

Industry Sector/carcinogenic agent	Shift work	Silica	Solar Radiation	Soots	Steel foundry workers	inorganic- acid mists containing	TCDD	Tetrachloroe thylene	Tin miners	Trichloroeth ylene	۸N	Vinyl chloride	Welders	Wood dust	Overall	Rank
Welfare institutions			0												11	51
Wholesale and retail trade and restaurants and hotels			6				7								269	11
Total Service industries	1,957		402	60		0	7	94		2		0		1	4,177	
TOTAL	1,957	907	1541	60	29	122	316	165	2	7	7	3	175	56	13,679	

3.4 DEATHS AND REGISTRATIONS BY INDUSTRY SECTOR AND CANCER SITE

Tables 6 and 7 give total deaths and total registrations respectively, by industry sector and for each cancer site. Numbers of deaths and registrations for males, females and the total are available on the HSE website, together with the respective attributable fractions. The totals and ranking for industry sector for Tables 6 and 7 are the same as in Tables 4 and 5 respectively.

In addition to the contribution of multiple carcinogens in many industry sectors these tables highlight the multiplicity of types of cancer within industry sectors. For example, from Table 7, there are 7 for farming (brain, leukaemia, lung, multiple myeloma, non-Hodgkin's lymphoma, NMSC, soft tissue sarcoma, (9 for construction (bladder, brain, larynx, lung, mesothelioma, NMSC, oesophagus, sinonasal and stomach), and 12 for personal and household services (bladder, cervix, kidney, leukaemia, lung, mesothelioma, non-Hodgkin's lymphoma, oesophagus, ovary, sinonasal, stomach).

Table 6 Total deaths by industry sector and cancer site

Industry Sector/Cancer site	Bladder	Bone	Brain	Breast	Cervix	Kidney	Larynx	Leukaemia	Liver	Lung	Е	Melanoma eye	Mesothelioma
Farming			7					8		35			
Forestry			0					0		1			
Horticulture			2					3		11			
Total agricultural, hunting, fishing and forestry			9					11		47			
Beverage industries	0				0			0		3			
Crude petroleum and natural gas production	0				0		0	0		4			
Electricity, gas and steam	0	0			0		0	0	0	19			10
Food manufacturing	0		0		0			0	0	10			
General industry		0						0	0	0			
Iron and steel basic industries	9		0		0		1	0		52			
Manufacture of electrical machinery, apparatus, appliances, supplies	0		0		0	0	2		0	28			
Manufacture of fabricated metal products, (not machinery and equipment)	0				1	0	2	0	0	60			
Manufacture of footwear										0			
Manufacture of furniture and fixture, except primary of metal	0							2		16			
Manufacture of glass and glass products	0				0			0		42			
Manufacture of industrial chemicals	0		0				2	0	1	62	0		34
Manufacture of instruments, photographic and optical goods	19								0	28			
Manufacture of leather and products of leather or of its substitutes	3				0		0			2			
Manufacture of machinery except electrical	0	0			1	0	2	0	0	71			
Manufacture of miscellaneous products of petroleum and coal	0							0		1			
Manufacture of other chemical products	0		0				3	0	1	66	0		36
Manufacture of other non-metallic mineral products	1							0		58			
Manufacture of paper and paper products	0				0		1	0		31	0		19
Manufacture of plastic products not elsewhere classified	0		0					0	1	8	0		
Manufacture of pottery, china and earthenware					0		0			54			
Manufacture of rubber products	0	0	0				1	0		1	0		
Manufacture of textiles	11				0			1		3			
Manufacture of transport equipment	0				0	0	2		0	92			60
Manufacture of wearing apparel, except footwear	0				0	0		2	0	4			
Manufacture of wood and wood and cork products, except furniture	0							2		46			

Industry Sector/Cancer site	adder	Bone	Brain	ßreast	cervix.	idney	arynx	aemia	Liver	Lung	E	noma _eye	lioma
	B			ш	0	×	Ē	Leuk				Mela	Mesothe
Metal Workers	112									152			
Mining	3		0					0	0	215			14
Non-ferrous metal basic industries	1	0	0		0		2	0	0	111			
Other manufacturing industries	0									4			
Painters (not construction)	7									59			
Petroleum refineries	0		0				0	0	0	18	0		20
Printing, publishing and allied industries	0		0		0					241			
Tobacco manufacture	0				0					0			
Water works and supply	0				0					2			
Welders										152		1	
Total manufacturing industry, mining, quarrying, electricity, gas, water	166	0	1		3	1	17	8	4	1,667	0	1	192
Construction	18		1		0		2	0		2,085			1,441
Painters and decorators (construction)	24									187			
Roofers, road surfacers, Roadmen, Paviors (Construction)													
Total Construction	42		1		0		2	0		2,251			1,441
Air transport	0				0		0	0	0	14			
Business, professional and other organisation										2			
Communication	0				0					11			
Education services	0				0			0	0	16	0		
Financing, insurance, real estate and business services										52			
Flight Personnel		0		4				0	0	0			
Land transport	21	0			0		0	0	0	328			69
Medical, dental, other health and veterinary services	0	0						0	0	12	0		
Personal and household services	17				4	0		3	0	308			193
Public administration and defence	0									29			
Recreational and cultural services										12			
Research and scientific institutes	0	0			0			0	0	2	0		
Sanitary and similar services	0							0	0	17			7
Services allied to transport	2	0			0			0	0	31			
Shift work				552		1							
Water transport	0				0			0	0	8			

Industry Sector/Cancer site	Bladder	Bone	Brain	Breast	Cervix	Kidney	Larynx	Leukaemia	Liver	Lung	ГН	Melanoma _eye	Mesothelioma
Welfare institutions										10			
Wholesale and retail trade and restaurants and hotels	0							1		197			35
Total Service industries	41	0		555	4	0	0	5	1	1,039	0		304
TOTAL	245	0	11	555	7	1	20	24	5	4,749	0	1	1,937

Table 6: Continued

Industry Sector/Cancer site	Multiple Iyeloma	oharynx	NHL	NMSC	phagus	Ovary	ancreas	lonasal	STS	tomach	Thyroid	Total	Rank
	- 2	Nasop			Oeso		Pa	Sir		Ó			
Farming	4		9	1					0			65	19
Forestry	0	0	0	0				0	0			2	55
Horticulture	2		3						0			21	34
Total agricultural, hunting, fishing and forestry	6	0	13	1				0	1			88	
Beverage industries					0			0				4	53
Crude petroleum and natural gas production					0			0				4	51
Electricity, gas and steam				0	2			0		0	0	33	30
Food manufacturing	0			0	2			0				12	39
General industry											0	0	59
Iron and steel basic industries			14	0	1			0	6	1		84	16
Manufacture of electrical machinery, apparatus, appliances, supplies			0		5			0		2		39	27
Manufacture of fabricated metal products, (not machinery and equipment			1	0	10			1				75	18
Manufacture of footwear								7				7	47
Manufacture of furniture and fixture, except primary of metal		2						3				22	33
Manufacture of glass and glass products		0	5	0	0			0	2			49	26
Manufacture of industrial chemicals	0		2				1	0	0	1		103	14
Manufacture of instruments, photographic and optical goods				1				2				49	25
Manufacture of leather and products of leather or of its substitutes					0			3				8	46
Manufacture of machinery except electrical			1		14			2			0	91	15
Manufacture of miscellaneous products of petroleum and coal												1	58
Manufacture of other chemical products							0	0		1		107	13
Manufacture of other non-metallic mineral products			2	0				0	1			61	20
Manufacture of paper and paper products					2			0	0	0		53	22
Manufacture of plastic products not elsewhere classified								0		2		11	41
Manufacture of pottery, china and earthenware			4	0	0			0	2			60	21
Manufacture of rubber products							0	0		4		7	48
Manufacture of textiles		0			2			0				17	35
Manufacture of transport equipment			0	0	4			1		1		162	10
Manufacture of wearing apparel, except footwear		0	0	0	3			0				10	43
Manufacture of wood and wood and cork products, except furniture		1	1	0				2	0			52	24

Industry Sector/Cancer site	Multiple Myeloma	Nasopharynx	NHL	NMSC	Oesophagus	Ovary	Pancreas	Sinonasal	STS	Stomach	Thyroid	Total	Rank
Metal Workers				6				13				283	5
Mining				0						2	0	235	9
Non-ferrous metal basic industries			4	0	0			0	2	2		121	12
Other manufacturing industries								0				4	52
Painters (not construction)										13		79	17
Petroleum refineries				0				0		0		38	28
Printing, publishing and allied industries				0	2			1		0		245	7
Tobacco manufacture					0			0				0	60
Water works and supply				0	0							3	54
Welders												153	11
Total manufacturing industry, mining, quarrying, electricity, gas, water	0	4	33	8	48		1	33	12	32	0	2,231	
Construction		4		7	10			6		31		3,605	1
Painters and decorators (construction)										43		254	6
Roofers, road surfacers, Roadmen, Paviors (Construction)				4								4	50
Total Construction		4		11	10			6		74		3,843	
Air transport					1			0				15	37
Business, professional and other organisation				0								2	57
Communication				0	0			0				11	42
Education services		0			0			0				16	36
Financing, insurance, real estate and business services				0								52	23
Flight Personnel											0	4	49
Land transport				0	3			0		1	0	423	4
Medical, dental, other health and veterinary services		0		0				0			0	13	38
Personal and household services		0	11	0	122	23		3		1		686	2
Public administration and defence				2								31	31
Recreational and cultural services				0								12	40
Research and scientific institutes		0		0	0		0	0			0	2	56
Sanitary and similar services				0				0		0	0	25	32
Services allied to transport				0	0			0				33	29
Shift work												552	3
Water transport				0	0			0				9	45

Industry Sector/Cancer site	Multiple Myeloma	Nasopharynx	NHL	NMSC	Oesophagus	Ovary	Pancreas	Sinonasal	STS	Stomach	Thyroid	Total	Rank
Welfare institutions				0								10	44
Wholesale and retail trade and restaurants and hotels			1	0					0	0		235	8
Total Service industries		0	11	3	126	23	0	3	0	3	0	2,120	
TOTAL	6	8	57	23	184	23	1	39	13	108	0	8,019	

	1	r	1		r	1		1	1				
Industry Sector/Cancer site	Bladder	Bone	Brain	Breast	Cervix	Kidney	Larynx	Leukaemia	Liver	Lung	£	Melanoma eye	Mesotheliom a
Farming			8					13		40			
Forestry			0					1		1			
Horticulture			3					5		12			
Total agricultural, hunting, fishing and forestry			11					19		54			
Beverage industries	0				0			0		4			
Crude petroleum and natural gas production	0				0		0	0		4			
Electricity, gas and steam	0	0			0		0	0	0	22			10
Food manufacturing	0		0		0			0	0	12			
General industry		0						0	0	0			
Iron and steel basic industries	20		0		0		3	0		60			
Manufacture of electrical machinery, apparatus, appliances, supplies	0		0		1	0	5		0	32			
Manufacture of fabricated metal products, (not machinery and equipment)	0				1	0	6	0	0	68			
Manufacture of footwear										1			
Manufacture of furniture and fixture, except primary of metal	0							3		18			
Manufacture of glass and glass products	0				0			0		48			
Manufacture of industrial chemicals	1		0				6	0	1	71	0		34
Manufacture of instruments, photographic and optical goods	44								0	32			
Manufacture of leather and products of leather or of its substitutes	8				0		1			2			
Manufacture of machinery except electrical	0	0			2	1	5	0	0	81			
Manufacture of miscellaneous products of petroleum and coal	0							0		1			
Manufacture of other chemical products	0		0				7	0	1	75	0		36
Manufacture of other non-metallic mineral products	2							0		66			
Manufacture of paper and paper products	0				0		3	0		35	0		19
Manufacture of plastic products not elsewhere classified	0		0					0	1	9	0		
Manufacture of pottery, china and earthenware					0		0			62			
Manufacture of rubber products	0		0				3	0		1	0		
Manufacture of textiles	23				0			1		3			
Manufacture of transport equipment	0				1	1	4		0	106			60
Manufacture of wearing apparel, except footwear	0				0	0		4	0	4			
Manufacture of wood and wood and cork products, except furniture	0							3		52			

Table 7 Total cancer registrations by industry sector and cancer site

Industry Sector/Cancer site								_					۶
	Bladder	Bone	Brain	Breast	Cervix	Kidney	Larynx	Leukaemia	Liver	Lung	Н	Melanoma eye	Mesothelior a
Metal Workers	252									174			
Mining	6	0	0					0	0	247			14
Non-ferrous metal basic industries	1		0		0		5	0	0	127			
Other manufacturing industries	0									5			
Painters (not construction)	16									67			
Petroleum refineries	0		0				0	0	0	20	0		20
Printing, publishing and allied industries	0		0		0					277			
Tobacco manufacture	0				0					0			
Water works and supply	0				0					3			
Welders										175		6	
Total manufacturing industry, mining, quarrying, electricity, gas, water	372	0	1		6	2	49	13	4	1,911	1	6	192
Construction	41		1		0		7	0		2,399			1,441
Painters and decorators (construction)	56									215			
Roofers, road surfacers, Roadmen, Paviors (Construction)													
Total Construction	96		1		0		7	0		2,591			1,441
Air transport	0				0		0	0	0	16			
Business, professional and other organisation										2			
Communication	0				0					12			
Education services	0				0			0	0	18	0		
Financing, insurance, real estate and business services										60			
Flight Personnel		0		13				0	0	1			
Land transport	48	0			0		0	1	0	377			69
Medical, dental, other health and veterinary services	0	0						1	0	14	0		
Personal and household services	36				11	1		5	0	349			193
Public administration and defence	0									33			
Recreational and cultural services										13			
Research and scientific institutes	0	0			0			0	0	2	0		
Sanitary and similar services	0	0						0	0	19			7
Services allied to transport	4				0			0	0	36			
Shift work				1,957									
Water transport	0				0			0	0	9			
Welfare institutions										11			

Industry Sector/Cancer site	Bladder	Bone	Brain	Breast	Cervix	Kidney	Larynx	Leukaemia	Liver	Lung	Н	Melanoma _eye	Mesotheliom a
Wholesale and retail trade and restaurants and hotels	0							1		224			35
Total Service industries	90	0		1,969	11	1	1	8	1	1,184	0		304
TOTAL	550	0	14	1,969	18	3	56	40	5	5,447	1	6	1,937

Tab	le	7	Continued	ł
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Industry Sector													
		arynx			suge		s	al		_			
	tiple	sopha		ပ္စ	sophi	<u>ک</u>	crea	onas	<i>(</i> 0	mach	roid	a	¥
	Mul	Nas	IHN	ŴN	Oes	0va	Pan	Sin	STS	Sto	Thy	Tot	Rar
Farming	7		22	128					1			220	12
Forestry	0	0	1	7				1	0			11	50
Horticulture	3		8						0			31	36
Total agricultural, hunting, fishing and forestry	10	0	31	135				1	1			263	
Beverage industries					0			0				4	55
Crude petroleum and natural gas production					0			0				5	53
Electricity, gas and steam				53	2			0		0	0	89	25
Food manufacturing	0			1	2			0				15	45
General industry											0	0	59
Iron and steel basic industries			34	4	1			1	12	2		135	17
Manufacture of electrical machinery, apparatus, appliances, supplies			1		5			1		3		49	32
Manufacture of fabricated metal products, (not machinery and equipment)			2	1	10			5				94	24
Manufacture of footwear								22				22	39
Manufacture of furniture and fixture, except primary of metal		4						10				34	35
Manufacture of glass and glass products		0	12	1	0			0	4			64	29
Manufacture of industrial chemicals			4				1	1	1	2		121	19
Manufacture of instruments, photographic and optical goods				125				6				206	13
Manufacture of leather and products of leather or of its substitutes					0			10				20	40
Manufacture of machinery except electrical			2		14			6			0	111	20
Manufacture of miscellaneous products of petroleum and coal												1	58
Manufacture of other chemical products							0	0		2		123	18
Manufacture of other non-metallic mineral products			4	1				0	1			75	26
Manufacture of paper and paper products					2			0	0	0		61	31
Manufacture of plastic products not elsewhere classified								0		3		14	46
Manufacture of pottery, china and earthenware			9	23	0			0	3			98	22
Manufacture of rubber products							0	0		6		12	49
Manufacture of textiles		0			2			1				31	37
Manufacture of transport equipment			1	5	4			4		1		188	14
Manufacture of wearing apparel, except footwear		1	0	1	3			1				13	48
Manufacture of wood and wood and cork products, except furniture		3	2	2				7	1			69	28

Industry Sector													Τ
		ynx			sní								
	e na	har			hag		as	Isal		ch	σ		
	ltipl elor	dos	_	sc	sop	ary	JCre	onê	S	ma	/roi	a	논
	ΜΩ	Na:	ЧN	Σz	Ő	ŏ	Par	Sin	ST	Sto	τh)	Tot	Rai
Metal Workers				778				46				1,250	3
Mining				31						4	0	302	8
Non-ferrous metal basic industries			10	9	0			1	3	3		159	16
Other manufacturing industries								0	-			5	54
Painters (not construction)										19		102	21
Petroleum refineries				7				0		0		48	33
Printing, publishing and allied industries				3	2			4		0		286	9
Tobacco manufacture					0			0				0	60
Water works and supply				26	0							29	38
Welders												181	15
Total manufacturing industry, mining, quarrying, electricity, gas, water		7	80	1,066	49		1	111	25	46	0	3,944	
Construction		8		841	10			21		46		4,816	1
Painters and decorators (construction)										64		334	7
Roofers, road surfacers, Roadmen, Paviors (Construction)				541								541	5
Total Construction		8		1,370	10			21		109		5,656	
Air transport					1			0				18	42
Business, professional and other organisation				1								3	56
Communication				5	0			0				17	43
Education services		0			0			0				18	41
Financing, insurance, real estate and business services				3								63	30
Flight Personnel											0	14	47
Land transport				6	3			0		2	0	505	6
Medical, dental, other health and veterinary services		0		1				0			0	16	44
Personal and household services		0	28	14	125	33		9		2		804	4
Public administration and defence				240								273	10
Recreational and cultural services				55								69	27
Research and scientific institutes		0		1	0		0	0			0	3	57
Sanitary and similar services				68				0		0	0	95	23
Services allied to transport				3	0			0				43	34
Shift work												1,957	2
Water transport				1	0			0				11	52

Industry Sector	Multiple Myeloma	Nasopharynx	NHL	NMSC	Oesophagus	Ovary	Pancreas	Sinonasal	STS	Stomach	Thyroid	Total	Rank
Welfare institutions				0								11	51
Wholesale and retail trade and restaurants and hotels			2	6					1	0		270	11
Total Service industries		0	29	402	129	33	0	10	1	4	0	4,177	
TOTAL	10	16	140	2,928	188	33	1	133	27	158	1	13,679	

4.0 DISCUSSION

Our estimate of the fraction of current cancer deaths in the UK due to past occupational exposures is the upper limit of the range of 1%-5% suggested by Doll and Peto (2005). Burden estimates from other studies range between 3 and 10% (Dreyer *et al*, 1997; Driscoll *et al*, 2005; Steenland *et al*, 2003; Nurminen and Karjalainen 2001; Vineis and Simonato, 1991; Gustavsson *et al*, 200; Landrigan and Markowitz 1989; Leigh *et al*, 1997). This is partly due to differences in the numbers of cancers and carcinogens considered. For example the global estimate of occupational cancer (Driscoll *et al*, 2005) included only lung cancer, leukaemia and mesothelioma; their estimate for lung cancer included only 8 carcinogens, arsenic, asbestos, beryllium, cadmium, chromium, DEE, nickel and silica. The 13 additional agents in our study contributed 33% of the total attributable registrations from lung cancer. The relative importance of different cancer sites also changes as more cancer sites are included; for example, in this study with leukaemia (included in the global estimate) being less important than other sites including other haematopoietic malignancies such as non-Hodgkin's lymphoma.

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. For example, both the methods and results from the study are currently being utilised to inform an EU project to make recommendations (and to assess the socioeconomic impact) for new European Union Occupational Exposure Limits for 25 recognised carcinogens. It is also being used to underpin the on-going update of the World Health Organisation Global Burden of Disease.

However, assumptions made in our methodology and uncertainties and inaccuracies in the data we have used may have introduced biases into our estimates, the impact of which is not fully captured in the confidence intervals presented. Table 8 gives some of these and the direction of the impact of these on the estimation of the burden due to occupation. On-going work is exploring the sensitivity of the estimates to such sources of uncertainty and bias.

Agents classified by IARC by the end of 2008 as Group I and 2A carcinogens were assessed. Other substances, such as IARC group 2B carcinogens, many of which may be treated as if they were human carcinogens in regulatory settings have not yet been evaluated; our estimates could thus be too low. In addition, our estimates do not include evaluation of the results from the review and update by IARC of all group1 carcinogens carried out in 2009 in which a separate classification was given for all cancer sites that were relevant to specific carcinogens; these classifications could potentially vary between cancer sites for the same substance. For example, asbestos has recently been classified as group 1 for mesothelioma and cancers of the larynx, lung and ovary and as group 2A for colorectal, pharyngeal and stomach cancers (Straif *et al*, 2009).

Uncertainty or bias may have been introduced in the choice of the study for obtaining data for the risk estimates, for example if the exposures in the source study did not reflect those experienced in GB or distributions of confounders differed between the source population and GB. A major gap in available information was a lack of separate risk estimates for women and/or cancer incidence. The use of risk estimates derived from studies of men for women and mortality risk estimates for incidence may have

biased the AFs. Epidemiological studies of occupational groups are often confounded by a 'healthy worker effect' i.e. a reduced overall risk estimate compared to the general population. This together with potential misclassification of exposure in epidemiological studies could lead to an underestimation of the true effect and thus an underestimation of the burden.

Table 8: Uncertainties and limitations of the methodology and their potential impact on the estimate of the burden of disease due to occupation.

Source of Uncertainty	Potential impact on burden estimate
Exclusion of IARC group 2B and unknown carcinogens	\downarrow
Inappropriate choice of source study for risk estimate	$\uparrow \downarrow$
Imprecision in source risk estimate	$\uparrow \downarrow$
Source risk estimate from study of highly exposed workers applied to lower exposed target population	↑
Risk estimate biased down by healthy worker effect, exposure misclassification in both study and reference population	\downarrow
Inaccurate risk exposure period	$\uparrow \downarrow$
Unknown proportion exposed at different levels of exposure	$\uparrow \downarrow$
Effect of unmeasured confounders	$\uparrow\downarrow$

Most of the risk estimates from the published literature were related to some estimate of cumulative exposure. In assigning 'higher' and 'lower' categories to the CAREX industry groups implicit assumptions were made regarding the similarity of durations and intensities of exposure between the source and target (national) populations. National data are not generally available on the proportions of those exposed at different levels of exposure nor does the UK have a national job exposure matrix such as those developed in Finland and the US (Antilla *et al*, 1992; Greife *et al*, 1995). The ideal requirement for obtaining the risk estimates is a large good quality study carried out in Britain with quantitative exposure estimates for each of the cancers and carcinogens to be estimated. Unfortunately, these studies are rarely available. However, we have been careful to use estimates of relative risk from studies that were conducted in populations where exposure levels are representative of the level of risk to which British workers are likely to have been exposed.

Due to the long latent interval of many carcinogens our 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 (Cherrie *et al*, 2007). A comprehensive analysis of published exposure data, particularly in Western Europe and North America, has shown similar patterns of decreasing exposure patterns across a wide range of industries and substances (Symanski *et al*, 1998a,b). It should be noted that for many of the carcinogens in our study a major contribution to the burden was made by a large number of workers exposed at low levels and low risk for which our quantitative risk estimates are inevitably uncertain.

Our study has highlighted the fact that many workers may potentially be exposed to several carcinogens and that these may affect multiple cancer sites. Key carcinogens and industry sectors have been identified

posing varying challenges for risk reduction strategies. These include, asbestos, DEE, ETS (non-smokers), radon, silica, solar radiation and shift work.

Substantial exposure to asbestos in Britain until the 1970s has contributed to a continuing rise in asbestosrelated deaths from lung cancer and mesothelioma (Hodgson *et al*, 2005) and asbestos contributes 30% of the occupationally-related cancer registrations and nearly half of the deaths in our study. Exposure in the construction industry is highlighted in our study along with other dusts such as those containing silica. A recent case-control study of UK mesothelioma patients found high risks associated with exposure to asbestos in the construction industry including work as a plumber, electrician, painter or decorator (Rake *et al*, (2009). The authors suggest that a substantial proportion of the deaths in carpenters would be among those who installed asbestos installation board as fireproofing and the large amount of asbestos that remains in many older buildings may still be a potential hazard to construction workers involved in renovation, maintenance or asbestos removal. The difficulties of managing asbestos exposures arising during industrial maintenance and repair and the problems of health protection of workers worldwide has been discussed (Wagner, 2007).

Exposure to dusts containing silica is also highlighted in several industry sectors in our study, including the construction industry. Measurements of respirable crystalline silica in the UK construction industry have found levels that greatly exceed the current workplace exposure limit (WEL) of 0.1 mg/m³, particularly for work in confined spaces and without water suppression of dust or effective extraction (Chisholm, 1999).

Diesel engines have a wide range of industrial applications including on-road equipment (most heavy and medium duty trucks and buses use diesel engines) and off-road applications in the mining, rail, construction, distribution and farming industries and in the military, including the use of diesel-powered heavy equipment, locomotives, forklift trucks, ships, tractors and generators. In a recent review of the literature the highest levels of elemental carbon were reported for enclosed underground work sites in mining and construction (elemental carbon (EC): 27-658 μ g/m³) (Pronk *et al*, 2009). Intermediate levels were reported for above-ground semi-enclosed areas involving work as a workshop mechanic, dock worker and fire station workers (EC<50 μ g/m³), with the lowest levels (EC<25 μ g/m³) being reported for enclosed areas separated from the source such as drivers, train crew, parking attendants, vehicle testers and utility service workers.

Cancer in non-smokers due to workplace exposure to ETS may be expected to largely disappear in Britain in future due to the ban now in force; our results demonstrate the impact this exposure may have in countries where no ban is yet enforced. Carcinogens such as naturally occurring radon could also easily be eliminated from workplaces. Our study has extended evaluation of more 'traditional' industrial hazards such as asbestos to estimation of the effect of newer and less traditional problems. In 2007 IARC classified shift work, in particular night work, as being group 2A for breast cancer (Straif *et al*, 2007). The estimate of nearly 2000 breast cancer registrations due to shift work in our study is 54% of all female occupationally-related cancer registrations (1971/3622). The epidemiological evidence evaluated by IARC comes from population-based case-control studies and studies of nurses, marine telephone operators and female flight attendants although in the latter the effect of concomitant exposure to shift work and ionizing radiation is difficult to disentangle. Large studies in other industry groups with collection of good shift pattern data are needed. Denmark recently became the first country to designate breast cancer as an occupational disease for the purpose of receiving compensation (Commentary, 2009). The ramifications of this decision and results such as those in our study could be significant given the large numbers of women working night shifts in Britain and worldwide.

Exposure to solar radiation and mineral oils at work was associated with a large number of registrations from NMSC (21% of all attributable registrations). Mortality from NMSC is low but there may be substantial morbidity from disfigurement as the lesions tend to be on the head and neck and as the prevalence is high they represent a considerable economic burden to health services (Trakatelli *et al*, 2007; Houseman *et al*, 2003, Boyle *et al*, 2004) NMSC is thought to be substantially under-registered; our occupationally related figures are thus likely to be under-estimated.

On-going work and future reports will address (i) estimation of the burden due to occupational exposures using other measures such as years of life lost and Disability-Adjusted Life Years, (ii) the methodology that has been developed for predicting future estimates of the occupational cancers due to more recent exposures and application to important exposures identified from the current burden estimation results (iii) exploration of the sensitivity of the estimates to sources of uncertainty and bias.

Summary

This project is the first to quantify in detail the burden of cancer due to occupation specifically for Great Britain. 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; this can be compared with the impact of other causes of cancer. Prioritisation of risk reduction strategies should focus on those workplaces where such exposures are still occurring.

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6.0 STATISTICAL APPENDIX

Formulae used in the estimation of AF

1. Levin's equation

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

(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 = Pr(E|D)*(RR-1)/RRwhere Pr(E|D) = proportion of cases exposed (E = exposed, D = case) (2)

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

$$N_{e(\text{REP})} = \sum_{i=a}^{i=b} l_{(adj15)i} * n_0 / (\text{R-15}) \} + \sum_{k=0}^{k=(age(u)-age(1))} \sum_{j=c+k}^{j=d+k} \{ l_{(adj15)j} * n_0 * \text{TO} / (age(u)-age(1)+1) \}$$
(3)

Where:

 $N_{e(REP)}$ = 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)

 $l_{(adj15)i}$ = 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 turnour 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

 $Pr(E) = N_{e(REP)} / N_{p(REP)}$ (4) where $N_{p(REP)}$ = 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:

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

		Main Industry Sector	Adjustment factor for change in employment levels*	Turnover per year
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%

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

* 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 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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