I·I·A·C·

THE INDUSTRIAL INJURIES ADVISORY COUNCIL

POSITION PAPER 29

Lung Cancer and Foundry Workers

www.iiac.org.uk

INDUSTRIAL INJURIES ADVISORY COUNCIL

Professor K T PALMER, MA, MSc, DM, FFOM, FRCP, MRCGP (Chairman)

Professor Sir M AYLWARD, CB, MD, FRCP, FFPM, FFOM, DDAM

Professor M G BRITTON, MD, MSc, FRCP, Dip(Ind. Health)

Dr A COCKCROFT, MD, FRCP, FFOM, MB BS

Professor P CULLINAN, MD, MSc, FRCP, FFOM

Mr R EXELL, OBE

Mr P FAUPEL, Cbiol, MSB, MIRM, CFIOSH

Professor R GRIGGS, OBE, BA, PhD

Mrs D KLOSS, LLB, LLM

Dr I J LAWSON, MB BS, DRCOG, CMIOSH, FFOM, FACOEM

Mr S LEVENE, MA

Professor D McELVENNY, BSc, MSc, CStat, MSRP

Dr A SPURGEON, BSc, PhD, C. Psychol

Ms C SULLIVAN, MA, GradDipPhys, MCSF

Mr A TURNER, TechSP

Mr F M WHITTY, BA

Dr L WRIGHT, BMedSci, BMBS, FFOM

HSE Observer: Mr A DARNTON

IIAC Secretariat:

Secretary:	Mr G ROACH
Scientific Advisor:	Dr M SHELTON
Administrative Secretary:	Ms C HEGARTY
Assistant Administrative Secretary	Mrs Z HAJEE

Position Paper 29

Lung Cancer and Foundry Workers

Summary

1. In 1986 the Industrial Injuries Advisory Council (IIAC) published its Command Paper ‘Occupational Lung Cancer’ which included consideration of the risk of lung cancer in foundry workers.

2. At that time IIAC concluded that, although there was evidence of an increased risk of lung cancer in foundry workers, this was not sufficient to recommend prescription. However, the Council agreed to keep the subject under review.

3. A number of new studies including several large cohort studies have been published since 1986, and IIAC has therefore elected to carry out a review of this new evidence and to re-assess the case for prescription. This paper provides a summary of the evidence which IIAC has considered and sets out its conclusions and recommendations.

4. The cohort mortality studies and two morbidity studies suggest an increased risk of lung cancer in foundry workers when considered overall, but do not support a doubling of risk, an important criterion for prescription usually employed within the Industrial Injuries Scheme.

5. In addition, no strong evidence has been found of a doubling of risk associated with any specific type of work or duration of exposure within the foundry industry.

6. Findings in the case-control studies, the majority of which adjust for the effects of smoking (a major risk factor for lung cancer), tend to support those of the cohort studies.

7. The Council has concluded that evidence deriving from studies published since 1986 reinforces previous conclusions, and fails to make a sufficient case to recommend prescription for lung cancer in foundry workers.

This report contains some technical terms, the meanings of which are explained in a concluding glossary.

Introduction

8. In 1986 IIAC published its Command Paper 'Occupational Lung Cancer' which included consideration of the risk of lung cancer in foundry workers employed in iron and steel foundries. Having reviewed the published data at that time, the Council found evidence of an increased risk of lung cancer but insufficient evidence of a doubling of risk, an important criterion for prescription under the terms of the Industrial Injuries Disablement Benefit (IIDB) Scheme. IIAC was therefore unable to recommend prescription of lung cancer associated with foundry work, although it agreed to keep the matter under review. Since 1986 a number of new studies on this subject have been published, so IIAC elected to carry out a further review of the evidence. This paper summarises the basis for the Council's decision in 1986 and sets out the findings of the present review, together with IIAC's conclusions and recommendations.

The Industrial Injuries Disablement Benefit Scheme

9. IIAC is an independent statutory body set up in 1946 to advise the Secretary of State for Work and Pensions in Great Britain and the Department for Social Development in Northern Ireland on matters relating to the Industrial Injuries Scheme. The major part of the Council's time is spent considering whether the list of prescribed diseases for which benefit may be paid should be enlarged or amended.

10. The IIDB Scheme provides a benefit that can be paid to an employed earner because of an industrial accident or Prescribed Disease.

The legal requirements for prescription

11. The Social Security Contributions and Benefits Act 1992 states that the Secretary of State may prescribe a disease where s/he is satisfied that the disease:

    i. ought to be treated, having regard to its causes and incidence and any other relevant considerations, as a risk of the occupation and not as a risk common to all persons; and

    ii. is such that, in the absence of special circumstances, the attribution of particular cases to the nature of the employment can be established or presumed with reasonable certainty.

12. In other words, a disease may only be prescribed if there is a recognised risk to workers in an occupation, and if the link between disease and occupation can be established or reasonably presumed in individual cases.

13. In seeking to address the question of prescription for any particular condition, the Council first looks for a workable definition of the disease. It then searches for a practical way to demonstrate in the individual case that the disease can be attributed to occupational exposure with reasonable confidence. For this purpose, reasonable confidence is interpreted as being based on the balance of probabilities according to available scientific evidence.

14. Within the legal requirements of prescription it may be possible to ascribe a disease to a particular occupational exposure in two ways – from clinical features of the disease or from epidemiological evidence that the risk of disease is at least doubled by the relevant occupational exposure.

Clinical features

15. For some diseases attribution to occupation may be possible from specific clinical features of the individual case. For example, the proof that an individual's dermatitis is caused by his/her occupation may lie in its improvement when s/he is on holiday and regression when the person returns to work, and in the demonstration that they are allergic to a specific substance with which they come into contact only at work. It can also be that the disease *only* occurs as a result of an occupational hazard (e.g. coal workers' pneumoconiosis).

Doubling of risk

16. Other diseases are not uniquely occupational, and when caused by occupation, are indistinguishable from the same disease occurring in someone who has not been exposed to a hazard at work. In these circumstances, attribution to occupation on the balance of probabilities depends on epidemiological evidence that work in the prescribed job, or with the prescribed occupational exposure, increases the risk of developing the disease by a factor of two or more.

17. The requirement for, at least, a doubling of risk follows from the fact that if a hazardous exposure doubles risk, for every 50 cases that would normally occur in an unexposed population, an additional 50 would be expected if the population were exposed to the

hazard. Thus, out of every 100 cases that occurred in an exposed population, 50 would do so only as a consequence of their exposure while the other 50 would have been expected to develop the disease, even in the absence of the exposure. Therefore, for any individual case occurring in the exposed population, there would be a 50% chance that the disease resulted from exposure to the hazard, and a 50% chance that it would have occurred even without the exposure. Below the threshold of a doubling of risk only a minority of cases in an exposed population would be caused by the hazard and individual cases therefore could not be attributed to exposure on the balance of probabilities; above it, they may be.

18. The required epidemiological evidence should ideally be drawn from several independent studies, and be sufficiently robust that further research at a later date would be unlikely to overturn it.

19. Lung cancer has important non-occupational causes and does not have clinical features that allow attribution to work when it occurs in an occupational context. The case for prescription, therefore, rests on reliable evidence of a doubling or more of risk of the disease in exposed workers - in the context of this enquiry, in iron and steel foundry workers, after allowance for other non-occupational risk factors.

Lung cancer

20. Lung cancer is the second most common cancer in the United Kingdom with around 39,000 people diagnosed per year. The predominant risk factor for lung cancer is cigarette smoking (associated with 9 out of 10 cases). Other risk factors include exposure to certain substances, such as asbestos or radon, or familial predisposition. Over two-thirds of people diagnosed with lung cancer are over 65 years old.

21. Lung cancers can be classified into two types: small cell lung cancers and non-small cell lung cancers, based on the appearance of the tumour cells under a microscope. The latter is the most common form, and accounts for 80% of all lung cancers.

22. Symptoms of lung cancer include cough, shortness of breath, coughing up blood-stained sputum, chest pain and loss of appetite and weight. Lung cancer can be diagnosed by chest radiography, computer tomography (CT) or magnetic resonance imaging (MRI) scans, or bronchoscopy with lung biopsy. Treatments may include chemotherapy, radiotherapy or surgery. The prognosis for lung cancer is highly dependent on the progression and type of the tumour but is generally poor.

Foundry work

23. Foundry work involves the pouring (casting) of molten metal into a sand mould which is bound together with organic binders. When the metal has been cast and has cooled it is fettled, i.e. worked on by sanding and grinding to remove imperfections and irregularities. During the casting process a complex mixture of gases and fine particles (foundry fume) is generated as a result of the pyrolysis[1] of the carbon containing binders. The chemical composition of this fume varies according to the composition of the metal alloys and the composition of the sand and organic binders used in the moulds, but it contains a number of polycyclic aromatic hydrocarbons (PAHs) which are established carcinogens. In some foundries co-carcinogens such as chromium and nickel, silica dust and asbestos may also be present.

---

[1] Thermal decomposition at high temperatures in the absence of oxygen

24. Epidemiological studies have suggested an association between working in ferrous foundries and an increased risk of lung cancer. However, due to the variation in processes and mould-making chemistry within the industry it has not been possible to determine the particular agents associated with this increased risk. Those workers presumed to be at a higher risk of lung cancer from the inhalation of foundry fume include furnacemen and furnace repair and maintenance men, casters and moulders. Fettlers are considered less likely to be exposed to foundry fume but are nevertheless exposed to metal dust.

Consideration of the evidence

25. When IIAC first considered this subject in 1986 the available dataset consisted of five cohort mortality studies and a single case-control study. The evidence from these studies suggested an increased risk of lung cancer in foundry workers, but not risks that were more than doubled. A literature search carried out by the Council has identified a number of relevant studies which have been published since 1986. Thus, the evidence base has been considerably enlarged by the addition of 10 further cohort mortality studies, of which three contain nested case-control analyses, two morbidity studies, and six more case-control studies.

26. In cohort studies the rate of death due to lung cancer in foundry workers is compared with that in the general population, or in another worker population. Cohort studies typically overcome the practical problem of long latency (the many years investigators have to wait between exposure and cancer onset) by studying populations in retrospect using records of employment, linked with databases of cancer registration or death certification. Such studies usually focus on specific workforces and contain information about employment duration, sometimes supplemented by supporting exposure measurements. However, they rarely contain information on confounders such as the smoking habits of the workforce, an important factor in studying risk of lung cancer.

27. Of those cohort studies available in 1986, two involved the workforce in iron foundries (Decouflé and Wood 1979; Silverstein *et al* 1986) - one was based in a steel foundry (Fletcher and Ades 1984) and one in an iron and steel foundry (Koskela *et al*, 1976; Tola *et al,* 1979). The remaining cohort study involved union members of the International Moulders and Allied Workers Union (Egan-Baum *et al*, 1981). The findings of these studies and the conclusions reached by the Council in 1986 are summarised below.

28. Decouflé and Wood (1979) studied the mortality experience of 2,861 men employed for at least one month between 1938 and 1967. In the group as a whole there was no increased mortality from respiratory cancer compared with the general population.

29. Silverstein *et al* (1986) studied 278 workers employed for at least 10 years in a foundry producing iron castings and who died between 1970 and 1981. Proportional Mortality Ratios (PMRs) were calculated by reference to the US population for the comparable period. In this study information on smoking habits was obtained from relatives. The PMR for lung cancer for non-smokers was 0.96 (95% confidence interval (95% CI) 0.24 to 2.44), and for those who had ever smoked was 1.59 (95% CI 1.08 to 2.33).

30. Koskela *et al* (1976), with further follow-up by Tola *et al* (1979), studied the mortality of 3,876 men employed for at least three months between 1950 and 1972, sampled from a larger population of 15,401 workers in 20 iron, steel and non-ferrous foundries. Compared with the general population mortality from lung cancer was raised but not more than doubled (Standardised Mortality Ratio (SMR) 1.51, 95% CI 1.30 to 3.21).

31. Egan-Baum *et al* (1981) studied 3013 union members who died between 1971 and 1975, and a comparable reference population taken from the US death registry. PMR for white workers was 1.44 (p <[2]0.01) and for black workers, 1.76 (p<0.01).

32. In the single British study (Fletcher and Ades, 1984), which at the time was also the largest, involving 9,846 men first employed between 1946 and 1965 and followed to 1978, the risk of lung cancer was raised but not more than doubled. The SMR for all foundry occupations was 1.4 (95% CI 1.18 to 1.72) and that for all fettling shop occupations was 1.73 (95% CI 1.34 to 2.21).

33. On the basis of these studies the Council found some evidence of an increased risk of lung cancer in foundry workers overall, but at a level below that deemed sufficient for prescription.

34. In a few of these studies further consideration was given to the increased risk associated with specific occupations within foundry work and/or durations of employment. Koskela found that lung cancer mortality was higher in iron foundries than in foundries of other types, with an SMR of 2.70 (95% CI 1.30 to 4.97) for iron foundry workers who had at least five years of employment. By contrast, Silverstein reported an SMR of 1.51 (which was not statistically significant) for iron foundry workers who had been employed for more than 10 years. Decouflé and Wood found no doubling of risk in those with more than 5 years employment as a group overall, but in a sub-group with more than 5 years employment before 1938 (N=192) the risk was doubled (4 cases expected, 8 observed). This group was analysed separately on the grounds that improvements in workplace conditions, including increased mechanisation and improved ventilation, took place immediately post-war in the

[2] < means 'less than'.

foundry under study. They may, therefore, constitute a group which was subject to particularly high exposures, not typical of workplaces during the past 60 years.

35. Koskela reported that the higher mortality rates in iron foundries derived largely from increased deaths in moulders and coremakers (5 deaths observed, 1.5 expected, $p<0.05$). By contrast, Silverstein reported no deaths from lung cancer in this occupation. Moreover, in Silverstein's study, classification by job of longest service (finishing, foundry work, core-room work, mixed jobs and other) did not identify a doubling of risk in any occupation.

36. Similarly, Fletcher and Ades reported an SMR of 1.26 (95% CI 0.85 to 2.20) for moulders, finding a doubling of risk only in furnace repair workers (SMR 2.03, 95% CI 1.22 to 3.17).

37. Thus, findings prior to 1986 were inconsistent. The strongest evidence for a doubling of risk came from a single case-control study (Blot *et al* 1983) which found an Odds Ratio (OR) of 7.1 (95% CI 1.2 to 42.3) for foundry work in the steel industry.

38. Case-control studies compare people who have a given disease (cases) with people who do not (controls) in terms of exposure to one or more risk factors of interest. In these studies the opportunity often exists to ask about smoking habits and co-exposure to other lung carcinogens, and thus allow for these factors in the analysis. However, in population and hospital-based case-control studies the history of exposure is obtained retrospectively (usually by asking the subject) and may be subject to reporting bias. For example, those suffering from disease may be more likely to recall certain occupations or exposures than those not suffering from disease. In nested case-control studies, by contrast, cases and controls are drawn from the population of an original occupational cohort study and so more typically contain objective data on exposure.

39. Overall, because of their methodological limitations, less weight tends to be given to the evidence derived from case-control studies. In 1986, therefore, the Council felt unable to recommend prescription on the basis of a single such study which was largely unsupported by the results of the methodologically stronger cohort studies.

40. The results of relevant studies which have been published since 1986 are summarised below. For convenience these have been grouped in terms of the type of foundry involved.

41. Three cohort mortality studies involved iron foundry workers. Sitas *et al* (1989) studied records of 419 members of the South African Iron Moulders Union employed between 1961 and 1983. Comparing death rates with South African national rates they found an increased (but not more than doubled) risk of lung cancer mortality for foundry workers over the age of 65 (PMR 1.71, p = 0.03) and a risk in younger foundry workers (aged 20-64 years) which was not different to that expected on the basis of the South African national rates (PMR 0.84, p = 0.31). Increased risks were identified in specific occupations (journeymen and production moulders) but in no case were these risks more than doubled. Similarly, an increased risk, although below the threshold of a doubling of risk, was observed in moulders aged 65 years and over (PMR 1.71, p=0.03).

42. Andjelkovich *et al* (1990, 1992, 1994) studied 8,147 foundry workers employed for at least one month in a US iron foundry between 1950 and 1979. The SMR for lung cancer compared with the general US population was 1.23 (95% CI 0.96 to 1.54) for white workers and 1.32 (95% CI 1.02 to 1.67) for non-white workers. In neither case was there an association with length of employment. A nested case-control study (220 cases, 2,200 controls) included in this investigation found no doubling of risk for any specific occupation or length of employment. For example, for moulders with more than five years employment the OR was 1.12 (95% CI 0.48 to 2.60) and for coremakers it was 1.01 (95% CI 0.37 to 2.76).

43. Adzersen *et al* (2003) studied mortality in 17,708 German workers with at least one year of employment in an iron foundry. Participants had first been employed in a foundry between 1950 and 1985 and follow-up was to 1993. For all foundry workers, using the general German population as a reference standard, the SMR for lung cancer was 1.64 (95% CI 1.24 to 2.23). Analysis of dose-response relationships showed that mortality rates for lung cancer tended to decline with increasing duration of exposure.

44. Austin *et al* (1997) carried out a case-control study (231 cases, 408 controls) in an iron foundry and two engine manufacturing plants in the USA and found no evidence of an increased risk associated either with foundry work in general or with any specific occupation. The ORs, adjusted for smoking, for employment in the foundry compared with employment in the engine plants were <10 years 0.79, 95% CI 0.49 to 1.30; 10-19 years 1.1, 95% CI 0.66 to 1.80; ≥20 years 0.90, 95% CI 0.55 to 1.50.

45. Five studies involved workers employed in iron and steel foundries. Sherson *et al* (1991) carried out a record linkage incidence[3] study amongst 6,144 Danish foundry workers employed between 1967 and 1985. For the group as a whole the Standardised Incidence Ratio (SIR)[4] for lung cancer, based on incidence rates for the Danish population, was 1.30 (95% CI 1.12 to 1.51). Although there was a dose-response relationship in terms of duration of employment, the risk was less than doubled in those with the longest period of employment (>[5]30 years, SIR 1.85, 95% CI 1.39 to 2.45). Similarly, no doubling of risk was observed in any specific occupation. Thus, for foundry workers, including moulders and oven workers, the SIR was 1.21 (95% CI 0.98 to 1.50) and for core room workers was 1.31 (95% CI 0.70 to 2.24).

---

[3] An incidence study has the advantage of not being confined to recording deaths from the disease in question, but also including living cases in so far as these can be enumerated.

[4] Sherson adopts the term Standardised Morbidity Ratio. The comparable term Standardised Incidence Ratio (SIR) has been used here to avoid confusion with Standardised Mortality Ratio (SMR).

[5] > means 'greater than'.

46. Xu *et al* (1996a) studied mortality from 1980 to 1989 in 8,887 workers employed in an iron and steel works in China. Using local provincial mortality rates for reference they reported a PMR of 1.37 for lung cancer (95% CI 1.28 to 1.45). Further follow-up to 1993 by Hoshuyama *et al* (2000) included 121,846 workers and reported a PMR of 0.85 (95% CI 0.81 to 0.89) for all job types and 0.96 (95% CI 0.88 to 1.02) for blue-collar workers classified as exposed to a range of fifteen agents, which included PAHs.

47. In a linked nested case-control study, (610 cases and 959 controls), Xu *et al* (1996b) examined associations with particular jobs and durations of exposure. Data on smoking were collected from friends and relatives of deceased workers. For foundry work, dose-response analysis for employment duration identified a doubling of risk of lung cancer in one group, although the pattern of the relationship was inconsistent. Following adjustment for smoking, ORs for ever being employed, less than 15 years of employment, and more than 15 years of employment were 1.8 (95% CI 1.1 to 2.8), 2.7 (95% CI 1.3 to 5.7), and 1.4 (95% CI 0.8 to 2.4) respectively. It is possible that those who had worked for more than 15 years constituted a smaller group than those with shorter employment duration and as a result contributed relatively few cases. However, it is not possible to determine this from the published data.

48. Ahn *et al* (2006) carried out a morbidity study among 44,974 Korean iron and steel workers, first employed between 1968 and 2001 and followed up between 1988 and 2001. Compared to the general Korean population, the overall SIR for lung cancer was 0.58 (95% CI 0.04 to 0.82). Comparison with office staff at the plant showed a Standardised Rate Ratio (SRR) of 1.16 (95% CI 0.50 to 2.65) for production staff and 0.94 (95% CI 0.26 to 2.70) for maintenance staff. The risk declined with duration of exposure from 0.96 (95% CI 0.31 to 2.98) for those employed 1-5 years, to 0.51 (95% CI 0.16 to 1.71) for those employed 10-20 years.

49. Rodriguez *et al* (2000) carried out a case-control study comparing 144 cases and 558 controls derived from 24,400 workers who had been employed at an iron and steel plant in Spain between 1952 and 1995. The plant included workers employed in coke batteries, steel mills, blast furnaces, foundries and also clerical and administrative staff. The OR for employment in the foundry, with adjustment for smoking, was 1.64 (95% CI 0.69 to 3.91). Where foundry employment was the longest job, the adjusted OR was 1.91 (95% CI 0.74 to 4.93).

50. Five studies involved workers employed in steel foundries of which three were carried out by the same research group (Moulin *et al* 1990, 1993, 2000) in various French plants involved in the production of stainless steel and ferrochromium alloys. The first of these studies (Moulin *et al* 1990) involved 2,269 workers employed between 1952 and 1982. For all workers the SMR for lung cancer was 1.40 (95% CI 0.72 to 2.45). However, for workers exposed to chromium and nickel compounds and PAHs this was 2.04 (95% CI 1.02 to 3.64). In this study, data on smoking were obtained for 67% of the workforce. Smoking habits were considered similar in the two groups, suggesting that the difference was unlikely to be accounted for by smoking. The relationship between lung cancer risk and duration of employment showed an inconsistent pattern (non-exposed 0.32, 95% CI 0.01 to 1.77; <10 years 2.26, 95% CI 0.83 to 4.93; ≥10years 1.82, 95% CI 0.59 to 4.26). The authors suggest the lack of significantly increased risk in the exposed groups and the lack of a trend towards higher risk in those with higher exposure may be explained by the relatively small numbers of subjects in the study and hence a lack of statistical power to detect real differences between exposure groups.

51. Similar findings were reported in a second study (Moulin *et al* 1993) involving 4,227 workers employed between 1968 and 1984 in the production of stainless steel. Compared with French national rates the lung cancer SMR for all production workers was 1.32 (95% CI 0.94 to 1.80) and for workers involved in the melting and casting of stainless steel was 1.04 (95% CI 0.42 to 2.15). However, for stainless steel foundry workers the SMR was 2.29 (95% CI 1.14 to 4.09). Here the highest risk in foundry workers was observed in those with the longest employment, although a relationship with duration of employment was not entirely consistent (<10 years 2.11, 95% 0.69-4.92; 10-19 years 2.53, 95% CI 0.52 to 7.40; 20-29 years 1.53, 95% CI 0.04 to 8.50; 30+ years 3.33 95% CI 0.40 to 12.04). In this study smoking habits were obtained for 24% of the workforce. The data indicated that smoking, particularly heavy smoking (>20 cigarettes per day), was more prevalent in the workforce than the general population but the small percentage assessed makes it difficult to allow for the effect of smoking on excess lung cancer rates or to assess the role of smoking as a possible confounder in the association between foundry work exposure and lung cancer.

52. The third study by Moulin *et al* (2000) involved 4,897 workers (4,288 males and 609 females) employed between 1968 and 1991 at a stainless steel production plant. Follow-up was to the end of 1992. Using regional death rates for reference the SMR for lung cancer for the workforce as a whole was 1.19 (95% CI 0.88 to 1.55), and for males only (who were presumably directly involved with production) the SMR was 1.20 (95% CI 0.90 to 1.57). There was no evidence of an association between lung cancer mortality and duration of exposure. In an associated nested case-control study (54 cases and 162 controls) an OR (adjusted for smoking) of 2.76 (95% CI 0.54 to 14.1) was observed for workers employed in the forge, while for those employed in the foundry the adjusted OR was 0.98 (95% CI 0.33 to 2.92). Smoking data were obtained for 67% of cases and 73% of controls.

53. Sorahan *et al* (1989, 1994) studied a cohort of 10,438 workers employed for at least one year in a British steel foundry between 1946 and 1965, with follow-up to 1990. Using general population death rates for reference the SMR for lung cancer for all workers was 1.46 (95% CI 1.34 to 1.58). Analysis of rates for specific occupations indicated an increased risk for all foundry occupations (SMR 1.52 $p<0.001$), for furnace workers (SMR 1.77 $p<0.01$) and for those employed in fettling (SMR 1.81 $p< 0.001$), but these risks were not more than doubled. Risks tended to increase with years since first employment and years of employment but in no case was there evidence of a doubling of risk.

54. Bourgkard *et al* (2009) studied lung cancer mortality in 17,701 workers (16,742 males and 959 females) employed for at least one year in a French steel production plant between 1959 and 1997. Follow-up was from 1968 to 1998. In this study smoking histories were available for almost all of men and 72% of women. Compared with the local population lung cancer mortality among male workers was lower than expected (SMR 0.89, 95% CI 0.78 to 1.01), although it was slightly increased relative to national mortality rates (SMR 1.30, 95% CI 1.15 to 1.48). For women workers rates were lower than expected using both reference groups. At this plant no associations were found, after adjustment for smoking, between lung cancer mortality and exposure to several known or suspected carcinogens (silica, asbestos, and PAHs), and no relationship was found with length of employment or exposure intensity.

55. Finkelstein (1994) carried out a case-control study which included all certified male deaths from lung cancer between the ages of 45 and 75 years in two Canadian cities that had major steelworks. Cases (967) were matched to 2,827 controls. Overall, no increased risk associated with employment in a steelwork was observed, although there were increased risks associated with more than 5 years employment in a foundry (OR 1.94, 95% CI 0.70 to 5.20) or a blast furnace (OR 1.38, 95% CI 0.61 to 3.06). These figures are unadjusted for smoking however.

56. A study carried out in the UK (Sorahan *et al* 1995) investigated mortality in 521 workers employed for at least one year in an iron and brass foundry between 1922 and 1978. Follow-up was from 1946 to 1992. Compared with the general population the SMR for lung cancer was 1.07 (95% CI 0.64 to 1.67). There was no evidence of a doubling of risk associated with any specific duration of exposure.

57. Three further case-control studies, carried out since 1986, investigated foundry work without specifying the type of foundry. Burns and Swanson (1991) studied 5,935 lung cancer cases and 3,956 referent cases of colon and rectal cancer as part of a larger occupational cancer incidence study in Detroit, USA. Amongst 43 occupational groups they reported an OR, adjusted for smoking, of 3.11 (95% CI 1.65 to 5.83) for furnace workers.

58. Jöckel *et al* (1992) studied 194 cases, 194 hospital-based controls and 194 population controls in Germany. With adjustment for smoking they reported an OR of 4.8 (95% CI 1.15 to 20.16) for work as a smelter or foundryman.

59. Becher *et al* (1989) compared 335 cases of lung cancer occurring between 1980 and 1985 in Cracow, Poland, with 332 age and sex-matched controls. Following adjustment for smoking a consistent trend towards increased risks with length of employment in a foundry was observed, although a doubling of risks of was associated only with employment of 30 years or longer (OR 2.66, 95% CI 1.31 to 5.2). In this study smoking was identified as the strongest risk factor (20-40 pack-years, RR 4.22, 95% CI 2.90-6.14; >40 pack-years RR 6.40, 95% CI4.45-9.25).

Conclusions and Recommendations

60. A number of investigations of the possible association between lung cancer and foundry work have been carried out since the Council last considered this question in 1986. The majority of these have been cohort studies which have included a long period of follow-up. This relatively large dataset is supplemented by a number of case-control studies, also carried out since 1986.

61. Taken together, the evidence from cohort studies, which derives from investigations carried out in a number of different types of foundry, does not provide strong or consistent support for a doubling of risk of lung cancer in foundry workers. Although some studies have demonstrated an increased risk in foundry workers as a whole, only the two earlier French studies reported a risk which was more than doubled. In these studies workers were engaged in stainless steel production, which involved potential exposure to the known lung carcinogens chromium and nickel.

62. Some studies have demonstrated an increased risk in particular occupations within foundries, but risks were seldom more than doubled and not consistently in the same occupations.

63. Where duration of employment was considered, some studies found a doubling of risk in those with shorter employment duration and a less than doubling of risk in those with longer employment. In other studies, where risks increased with increasing duration of employment, no evidence was found that risks were as much as doubled, even in those with the longest durations of employment.

64. The case-control studies were similarly inconsistent. In two studies risks were more than doubled for certain occupations associated with foundry work; although the comparability of occupational definition between these two studies is uncertain. One study found a doubling of risk associated with protracted employment in a foundry. The remaining three studies failed to identify a doubling of risk associated with foundry work.

65. The Council has concluded that the results of studies published since 1986 serve to reinforce the view formed previously. Although several investigations have reported an increased risk of lung cancer in foundry workers, the evidence for a doubling of risk, either in foundry workers as a whole or in specific groups of foundry workers or workers with a sufficient length of exposure, is insufficiently consistent or compelling. The Council is therefore unable to recommend prescription of lung cancer associated with work in iron and steel foundries.

Diversity and equality

66. The Council is aware of issues of equality and diversity and seeks to promote these as part of its values. The Council has resolved to seek to avoid unjustified discrimination on equality grounds, including age, disability, gender reassignment, marriage and civil partnership, pregnancy and maternity, race, religion or belief, gender and sexual orientation. During the course of this review of lung cancer in foundry workers no diversity and equality issues were apparent. It should be noted, however, that the employment of women in this occupation is rare and that conclusions have been drawn from the results of studies involving only or mainly male workers.

Prevention

67. Substances in foundries are regulated under The Control of Substances Hazardous to Health Regulations 2002 (COSHH), (as amended).The Regulations require that work is not carried out which is liable to expose any employees to any substance hazardous to health unless a suitable and sufficient assessment has been made of the risks created by the work and appropriate measures taken to prevent exposure as far as is reasonably practicable, i.e. the costs in reducing exposure would not be grossly disproportionate to the benefits.

68. Where it is not reasonably practicable to prevent exposure by elimination or substitution with a safer substance or total enclosure, exposure must be adequately controlled by the use of appropriate work processes, systems and engineering controls and measures to control exposures at source. Suitable respiratory protective equipment may be used in addition where adequate control cannot be otherwise achieved. Those working in areas of the workplace where exposure is likely to happen should be informed of the hazards/risks and be provided with the appropriate training. Additionally, COSHH may require employers to arrange appropriate health surveillance. More information on COSHH can be found at http://www.hse.gov.uk/coshh/index.htm and COSHH essentials guidance sheets for silica in foundries can be found at http://www.hse.gov.uk/pubns/guidance/fdseries.htm

References

Adzersen K-H, Becker N, Steindorf K *et al.* 2003. Cancer mortality in a cohort of male German iron foundry workers. Am J Ind Med 43:295-305.

Andjelkovich DA, Mathew RM, Richardson RB *et al.* 1990. Mortality of iron foundry workers: I. Overall findings. J Occup Med 32(6):529-539.

Andjelkovich DA, Mathew RM, Yu RC *et al.* 1992. Mortality of iron foundry workers. II. Analysis by work area. J Occup Med 34(4):391-401.

Andjelkovich DA, Shy CM, Brown MH *et a.l* 1994. Mortality of iron foundry workers. III. Lung cancer case-control study. J Occup Med 36(12):1301-1309.

Anh Y-S, Park RM, Stayner L *et al.* 2006. Cancer morbidity in iron and steel workers in Korea. Am J Ind Med 49:647-657.

Austin H, Delzell E, Lally C *et al.* 1997. A case-control study of lung cancer at a foundry and two engine plants. Am J Ind Med 31:414-421.

Becher H, Jedrychowski W, Flak E *et al.* 1989. Lung cancer, smoking and employment in foundries. Scand J Work Environ Health 15:38-42.

Blot WJ, Brown LM, Pottern LM *et al.* 1983. Long cancer among long-term steel workers. Am J Epidemiol 117:706-716.

Bourgkard E, Wild P, Courcot B *et al.* 2009. Lung cancer mortality and iron oxide exposure in a French steel-producing factory. Occup Environ Med 66:175-181.

Burns PB, Swanson GM. 1991. The Occupational Cancer Incidence Surveillance Study (OCISS): Risk of lung cancer by usual occupation and industry in the Detroit Metropolitan Area. Am J Ind Med 19:655-671.

Decoufflé P, Wood DJ. 1979. Mortality patterns among workers in a gray iron foundry. Am J Epidemiol 109:667-675.

Egan-Baum E, Miller BA, Waxweiler RJ. 1981. Lung cancer and other mortality patterns among foundrymen. Scand J Work Envron. Health 7 (Suppl 4):147-155.

Finkelstein MM. 1994. Lung cancer among steelworkers in Ontario. Am J Ind Med 26:549-557.

Fletcher AC, Ades A. 1984. Lung cancer mortality in a cohort of English foundry workers. Scand J Work Environ Health 10:7-16.

Hoshuyama T, Pan G, Tanaka C *et al.* 2006. Mortality of iron-steel workers in Ashan, China: A retrospective cohort study. Int J Occup Environ Health 12:193-202.

Jökel K-H, Ahrens W, Wichmann H-E *et al. 1992*. Occupational and environmental hazards associated with lung cancer. Int J Epidemiol 21:202-213.

Koskela RS, Hernberg S, Kärävä R *et al.* 1976. A mortality study of foundry workers. Scand J Work Envron Health 2 (Suppl.1):73-89.

Moulin JJ, Portefaix P, Wild P *et al.* 1990. Mortality study among workers producing ferroalloys and stainless steel in France. Brit J Ind Med 47:537-543.

Moulin JJ, Wild P, Mantout B *et al.* 1993. Mortality from lung cancer and cardiovascular diseases among stainless-steel producing workers. Cancer Causes Control 4:75-81.

Moulin JJ, Clavel T, Roy D *et al.* 2000. Risk of lung cancer in workers producing stainless steel and metallic alloys. Int Arch Occup Environ Health 73:171-180.

Rodriguez V, Tardón A, Kogevinas M *et al.* 2000. Lung cancer risk in iron and steel foundry workers: A nested case-control study in Asturias, Spain. Am J Ind Med 38:644-650.

Sherson D, Svane O, Lynge E. 1991. Cancer incidence among foundry workers in Denmark. Arch Environ Health 46:75-81.

Silverstein M, Maizlish N, Park R. 1986. Mortality among ferrous foundry workers. Am J Ind Med 10:27-43.

Sitas F, Douglas AJ, Webster EC. 1989. Respiratory disease mortality patterns among South African iron moulders. Brit J Ind Med 46:310-315.

Sorahan T, Cooke MA. 1989. Cancer mortality in a cohort of United Kingdom steel foundry workers:1946-85. Br J Ind Med 46:74-81.

Sorahan T, Faux AM, Cooke MA. 1994. Mortality among a cohort of United Kingdom steel foundry workers with special reference to cancers of the stomach and lung. Occup Environ Med 51:316-322.

Sorahan T, Lister A, Gilthorpe MS *et al.* Mortality of copper cadmium alloy workers with special reference to lung cancer and non-malignant diseases of the respiratory system: 1946-92. Occup Environ Med 52:804-812.

Tola S, Koskela RS, Hernberg S *et al.* 1979. Lung cancer mortality among foundry workers. J Occup Med 21:753-760.

Xu Z, Pan GW, Liu LM *et al.* 1996a. Cancer risks among iron and steel workers in Ashan, China. Part I: Proportional mortality ratio analysis. Am J Ind Med 30:1-6.

Xu Z, Brown LM, Pan GW *et al.* 1996b. Cancer risks among iron and steel workers in Ashan, China, Part II: Case-control studies of lung and stomach cancer. Am J Ind Med 30:7-15.

Glossary of terms used in this report

Types of study

Case-control study: A study which compares people who have a given disease (cases) with people who do not (controls) in terms of exposure to one or more risk factors of interest. Have cases been exposed more than non-cases? The outcome is expressed as an **Odds Ratio**, a form of **Relative Risk**.

Cohort study: A study which follows those with an exposure of interest (usually over a period of years), and compares their incidence of disease or mortality with a second group, who are unexposed or exposed at a lower level. Is the incidence rate higher in the exposed workers than the unexposed/less exposed group? Sometimes the cohort is followed forwards in time ('prospective' cohort study), but sometimes the experience of the cohort is reconstructed from historic records ('retrospective' or 'historic' cohort study). The ratio of risk in the exposed relative to the unexposed can be expressed in various ways, such as a **Relative Risk** or **Standardised Mortality Ratio**.

Measures of association

Statistical significance and P values: Statistical significance refers to the probability that a difference as large as that observed, or more extreme still, could have arisen simply by chance. The smaller the probability, the less likely it is that the difference can be explained by chance alone, rather than being a real difference. By convention, when this probability is less than 5% ($p < 0.05$) a difference is described as being "statistically significant" Significance tests only describe association. Statistically significant associations are not necessarily causal and can arise due to bias or confounding (see below)

Odds Ratio (OR): A measure of the strength of association between exposure and disease. It is the odds of exposure in those with disease relative to the odds of exposure in those without disease, expressed as a ratio. For rare exposures, odds and risks are numerically very similar, so the OR can be thought of as a **Relative Risk**. *A value greater than 1.0 indicates a positive association between exposure and disease*. (This may be causal, or have other explanations, such as bias, chance or **confounding**.)

Standardised Mortality Ratio (SMR): A measure of the rate of mortality for a particular cause of death in a working population compared with the general population with adjustment for age, gender, calendar year and sometimes socio-economic status. The SMR is the ratio of the observed number of deaths (due to a given disease arising from exposure to a given risk factor) that occurs within the study population to the number of deaths that would be expected if the study population had the same rate of mortality as the general population (the standard).

By convention, SMRs (and proportional mortality ratios (PMRs) and standardised incidence ratios (SIRs) as described below) are usually multiplied by 100. Thus, an SMR (or PMR or SIR) of 200 corresponds to a RR of 2.0. For ease of understanding in this report, SMRs (or PMRs or SIRs) are quoted as if RRs, and are not multiplied by 100. Thus, *a value greater than 1.0 indicates a positive association between exposure and disease.* (This may be causal, or have other explanations, such as bias, chance or **confounding**.)

Proportional mortality ratio (PMRs): The proportional mortality ratio is the proportion of deaths in the study population from a specific disease divided by the proportion of deaths in the general population from that same specific disease.

Standardised incidence ratio (SIR): A measure of the rate of cancer incidence for a particular type of cancer in a working population compared with the general population, with adjustment for age, gender, calendar year and sometimes socio-economic status. The SIR is the ratio of the observed number of cancer cases (due to a given cancer arising from exposure to a given risk factor) that occurs within the study population to the number of deaths that would be expected if the study population had the same rate of cancer incidence as the general population (the standard). The alternative term, **Standardised Rate Ratio** (SRR) is sometimes used when the rates being compared are incidence rates (i.e. new cases of disease per unit of time).

The Standardised Rate Ratio (SRR) is a summary mortality or cancer incidence measure comparing the rate of death from a particular cause or rate of cancer incidence from a particular cancer type in a higher exposed group compared to a lower exposed group from the same study population. For example, the rate in workers on a shop floor could be compared to those that work in offices at the same factory. The rate of disease in the higher exposed group (after adjustment for age, gender, year and sometimes socio-economic status) is divided by the similarly adjusted rate from the lower or unexposed group. The resulting ratio can be thought of as a type of **Relative Risk.**

Other technical terms

Confidence Interval (CI): The **Relative Risk** reported in a study is only an *estimate* of the true value in the underlying population; a different sample may give a somewhat different estimate. The CI defines a plausible range in which the true population value lies, given the extent of statistical uncertainty in the data. The commonly chosen 95%CIs give a range in which there is a 95% chance that the true value will be found (in the absence of bias and confounding). *Small studies involve more uncertainty and a wide range, whereas very large studies provide a narrower range of values*.

Confounding: Arises when the association between exposure and disease is explained in whole or part by a third factor (confounder), itself a cause of the disease, which occurs to a different extent in the exposure groups being compared.

For example, smoking is a cause of lung cancer and tends to be more common in blue-collar jobs. An apparent association between work in the job and lung cancer could arise because of differences in smoking habit, rather than because of exposure to a noxious work agent. Studies often try to mitigate the effects of ('control for') confounding in various ways such as: restriction (e.g. only studying smokers); matching (analysing groups with similar smoking habits); stratification (considering the findings separately for smokers and non-smokers); and mathematical modelling (statistical adjustment).

Report published
March 2011