Mortality from cancer and chronic respiratory diseases among workers who manufacture carbon electrodes

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Abstract

***Objectives*—To investigate the risk of cancer and non-neoplastic respiratory diseases among workers who manufacture carbon electrodes, as this industry entails exposure to mixtures of polycyclic aromatic hydrocarbons.**

***Methods*—A historical cohort study was carried out of 1006 male workers employed for at least 1 year between 1945 and 1971 in a carbon (graphite) electrode production plant in central Italy, who were followed up for mortality between 1955 and 1996. The ratio of observed to expected deaths (standardised mortality ratios, SMRs) was computed from both national and (for the period 1964–96) regional age and period specific mortalities. A multivariate Poisson regression analysis was performed to investigate the relative risk (RR) of death according to duration of employment and time since first employment in the factory.**

***Results*—A total of 424 workers had died, 538 were still alive, and 44 were lost to follow up. Mortalities from all causes, all cancers, and respiratory tract cancer were in line with the regional figure. An excess was found over the expected deaths from skin cancer including melanoma (SMR 3.16, 95% confidence interval (95% CI) 0.65 to 9.23) and from non-neoplastic respiratory diseases (SMR 1.58, 95% CI 1.16 to 2.11). Poisson regression analysis including age as a covariate showed an increased risk of dying from gastric cancer with increasing duration of employment, and an increase in the RR of dying from lung cancer and from non-neoplastic respiratory diseases with increasing time since first employment, although the linear trend was not significant.**

***Conclusion*—This study supports previous findings that working in the carbon electrode manufacturing industry may not increase the risk of dying from respiratory cancer. However, a possible association with non-malignant respiratory diseases cannot be excluded.**

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Keywords: carbon electrode manufacturing; polycyclic aromatic hydrocarbons; historical cohort study

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Carbon electrode manufacturing is one of the many industrial processes involving coal and petroleum products, with potential exposure to coal pitch and petroleum pitch. These productions entail exposure to mixtures of polycyclic aromatic hydrocarbons (PAHs), some of which may be carcinogenic to humans.[1] An increased risk of lung, skin, and bladder cancer has been reported among workers with occupational exposure to PAHs.[2] However, the results from the only three cohort studies of carbon electrode production workers carried out so far are inconclusive, possibly due to the relatively few subjects enrolled or the short duration of follow up.[3–5]

We aimed to investigate whether there was an excess of deaths from neoplasms and non-neoplastic diseases attributable to working at a carbon (graphite) electrode production plant in Italy. Previous studies carried out in this plant showed high concentrations of PAHs and mutagens in the working environment[6] and high concentrations of mutagens in the urine of workers.[7] Also, exposure to high concentrations of PAHs was found in various working areas in another graphite electrode producing plant.[8] Furthermore, higher mean values of 1-hydroxypyrene in end of shift urine[9] and higher concentrations of benzo(a)pyrene diolepoxide adducts to albumin[10] were found among workers exposed to PAHs at this and a similar plant in Italy.

Methods

POPULATION

The characteristics of the factory and its production processes have been reported in detail previously.[6 7] Briefly, the factory is located in Umbria, a region in central Italy, and has been manufacturing various carbon products since 1901. From 1945 to 1971, the factory produced carbon electrodes used in metallurgy, carbon brushes, and small carbon specialties. Petroleum derived coke, coal tar pitch, and petroleum tar pitch were all used as raw materials. Petroleum coke was used as the basis whereas pitches were used as binding material. The manufacturing process consisted of grinding and mixing the raw material and the binder, forming a crude paste, and then heating it at 800°C–1000°C in the baking area. Then electrodes were impregnated with liquid pitch under pressure and baked again at 250°C. During these activities, working exposure to fumes including PAHs may have occurred. Afterwards, electrodes underwent graphitisation at 2800°C, finishing touches, and shipping.

Personnel files from the plant registers were examined to collect information on dates of

Table 1 Standardised mortality ratios (SMRs) by selected causes of death (1945–96, with the Italian population as the reference)

Cause of death by ICD-8 codes	*Observed deaths (n)*	*Expected deaths (n)*	*SMR*	*95% CI*
All causes (001–999)	424	498.8	0.85	0.77 to 0.93
All malignant neoplasms (140–208)	125	148.2	0.84	0.70 to 1.00
Buccal cavity and pharynx (140–149)	5	4.7	1.05	0.34 to 2.46
Oesophagus (150)	3	3.6	0.84	0.17 to 2.45
Stomach (151)	20	18.3	1.09	0.67 to 1.69
Colon (153)	10	7.7	1.30	0.62 to 2.39
Liver, gall bladder, and bile duct (155–156)	4	8.7	0.46	0.13 to 1.18
Larynx (161)	4	5.1	0.79	0.21 to 2.02
Trachea, bronchus, and lung (162)	34	44.2	0.77	0.53 to 1.08
Skin, including melanoma (172–173)	3	1.3	2.29	0.47 to 6.69
Prostate (185)	10	8.3	1.20	0.58 to 2.21
Testis (186)	2	0.4	5.71	0.69 to 20.61
Bladder (188)	7	6.7	1.04	0.42 to 2.14
Kidney (189)	2	2.8	0.70	0.08 to 2.53
Ill-defined and unspecified sites (195, 199)	7	4.6	1.52	0.61 to 3.13
Lymphatic and haematopoietic tissue (200–208)	9	9.6	0.94	0.43 to 1.78
Circulatory system (390–459)	181	199.8	0.91	0.78 to 1.06
Respiratory system (460–519)	48	37.2	1.29	0.95 to 1.71
Digestive system (520–579)	24	41.2	0.58	0.37 to 0.86
External causes of death (800–999)	13	31.0	0.42	0.22 to 0.72

hire and resignation. More detailed data on job titles and smoking habits were not available. We restricted the cohort to workers hired after 1 January 1945 because the quality of data on employment was questionable before that date.

The data analysis was performed among men only due to the few women working at the factory. We included only workers who had worked at the factory for at least 1 year before 31 December 1971, resulting in a total of 1006 subjects. All workers were considered as equally exposed and duration of employment was used as a proxy for cumulative exposure to PAHs. The follow up lasted from 1955 to 1996. The mean (range) follow up was 39.5 (1.5–51.9) years. The vital status at the end of follow up was assessed by consulting the municipality registers, which were regularly updated as is usual in industrialised countries. The causes of death were coded with the 8th revision of the international classification of diseases, injuries, and causes of death (ICD-8).

DATA ANALYSIS

Each man contributed person-years at risk from the date of employment to date of death, end of follow up, or last contact. The expected number of deaths was computed from both the national and regional rates for age and calendar period. The plant is actually located in a region with lower mortality than in the whole country from all causes, all neoplasms, lung and bladder cancers, and non-neoplastic respiratory diseases.[11–14] However, although the regional rates seemed more adequate than the national ones for calculating expected deaths, the population living in the region is small (822 459 inhabitants in 1994) so age and period specific rates for most single causes of death were unstable. Furthermore, the regional rates were only available for 1964–96. For these reasons, we calculated expected deaths from the national rates for the whole follow up period, and we used the regional rates for further analysis.

Standardised mortality ratios (SMRs) and their 95% confidence intervals (95% CIs) were computed as suggested.[15] Person-years and expected deaths were computed with the person-years programme for personal computer.[16] Poisson regression analysis was performed with the GLIM programme to calculate relative risks (RRs) and their 95% CIs[15] for the causes of death with at least one observed death in each of the categories considered.[17] All the models fitted included age and calendar period as covariates.

Results

Cohort members contributed a total of 34 248 person-years. Of the 1006 subjects in the cohort, 424 died during the follow up, 538 were alive at the end of the study and 44 were lost (4.4%). The number of deaths observed and expected from the national rates by cause or broad group of causes, the corresponding SMRs, and their 95% CIs are set out in table 1. Fewer than expected deaths were found for all causes, all malignant neoplasms, various single neoplasms including larynx and lung cancers, diseases of the circulatory and the digestive systems, and external causes. An excess of deaths was found for neoplasms of the skin including melanoma (SMR 2.29) and of the testis (SMR 5.71), and for non-malignant respiratory diseases (SMR 1.29), although they were all non-significant at $p<0.05$.

When the 1964–96 observed deaths were compared with expected deaths, computed from the regional rates, no differences were found for mortality from all causes (observed deaths n=390; SMR 0.95, 95% CI 0.86 to 1.05) and from all neoplasms (observed deaths n=121; SMR 1.0, 95% CI 0.82 to 1.18); a higher than expected ratio was found for deaths from skin cancer including melanoma (observed deaths n=3; SMR 3.16, 95% CI 0.65 to 9.23) and from non-neoplastic respiratory diseases (observed deaths n=46; SMR 1.58, 95% CI 1.16 to 2.11, data not shown in the tables).

Table 2 Relative risks (RRs) of death from all selected causes, by duration of employment

	Duration of employment (y)								
	1–9†		*10–19*			*20*			
Cause of death by ICD-8 codes	*Deaths (n)*	*RR*	*Deaths (n)*	*RR*	*(95% CI)*	*Deaths (n)*	*RR*	*(95% CI)*	*p Value test for trend*
All causes (001–999)	139	1	146	0.97	(0.75 to 1.25)	146	0.99	(0.73 to 1.35)	0.95
All malignant neoplasms (140–208)	30	1	42	1.19	(0.71 to 1.98)	42	1.40	(0.80 to 2.45)	0.24
Buccal cavity, pharynx, and larynx (140–149, 161)	2	1	2	0.74	(0.08 to 6.47)	2	2.03	(0.22 to 19.0)	0.43
Trachea, bronchus, and lung (162)	10	1	12	0.90	(0.36 to 2.25)	12	0.59	(0.22 to 1.61)	0.29
Stomach (151)	4	1	7	3.14	(0.75 to 13.1)	7	7.06	(1.27 to 39.3)	0.03
Bladder (188)	3	1	2	0.76	(0.09 to 6.25)	2	0.47	(0.05 to 4.45)	0.51
Non-malignant respiratory diseases (460–519)	17	1	18	0.81	(0.39 to 1.71)	18	0.62	(0.24 to 1.59)	0.32

†Reference category.
Results of Poisson regression analysis with age as a covariate.

Table 3 Relative risks (RRs) of death from all causes, all malignant neoplasms, buccal cavity, pharyngeal and laryngeal cancers together, stomach and bladder cancer, and non-neoplastic respiratory diseases for time since first employment with a Poisson regression analysis including age as a covariate

	Time since first employment (y)								
	1–9†		*10–19*			*20*			
Cause of death by ICD-8 codes	*Deaths (n)*	*RR*	*Deaths (n)*	*RR*	*(95% CI)*	*Deaths (n)*	*RR*	*(95% CI)*	*p Value test for trend*
All causes (001–999)	92	1	140	1.32	(0.94 to 1.85)	192	1.50	(0.98 to 2.29)	0.08
All malignant neoplasms (140–208)	18	1	45	1.51	(0.75 to 3.07)	62	1.46	(0.64 to 3.33)	0.56
Buccal cavity, pharynx, and larynx (140–149, 161)	1	1	2	0.62	(0.04 to 9.18)	6	0.79	(0.04 to 17.3)	1.00
Trachea, bronchus, and lung (162)	7	1	11	1.38	(0.39 to 4.80)	16	2.06	(0.49 to 8.72)	0.28
Stomach (151)	4	1	9	0.90	(0.18 to 4.46)	7	0.36	(0.04 to 2.9)	0.24
Bladder (188)	2	1	1	0.43	(0.01 to 11.7)	4	1.73	(0.05 to 59.1)	0.47
Non-malignant respiratory diseases (460–519)	9	1	15	1.25	(0.47 to 3.29)	24	1.96	(0.57 to 6.69)	0.26

†Reference category.

Poisson regression analysis was performed according to duration of employment and time since first employment on mortality from all causes, all cancers, some cancer sites, and from non-neoplastic respiratory diseases (table 2). No significant increase in the relative risk with increasing duration of employment was apparent for mortality from all causes and most single causes. However, a significant increase in the relative risk of dying from stomach cancer with increasing duration of employment was found (p for trend=0.02).

Analysis of mortality for time since first employment showed an increased risk of death for many cancer sites, notably the lung, and for non-neoplastic respiratory diseases among subjects with ⩾20 years since first employment, although it was not significant (table 3).

Discussion

Previous studies showed that workers in this factory were exposed to high concentrations of airborne PAHs and mutagens and that they also excreted higher concentrations of mutagens in urine than unexposed controls.[6 7] We performed a historical cohort study to assess whether, in line with environmental and individual exposure data, employment in this factory caused an excess of deaths from cancer. As data on specific job titles were not available, non-differential misclassification of exposure may have occurred in our study, resulting in dilution of the risk of death due to exposure to PAHs. A recent study showed that about half of the workers are substantially exposed to PAHs.[9] It can be argued that more than half the workers had been exposed to PAHs in the past decades due to changes in the manufacturing process occurring in the study period in the plant. Therefore, the dilution effect of the risk of death due to occupational exposure in the factory is probably not highly relevant.

A small deficit in mortality from all causes, all neoplasms and diseases of the circulatory system was found when the national rates were used. However, the cohort members lived in the Umbria region, which has lower death rates than Italy as a whole for these causes.[11–14] In fact, these deficits disappeared when the regional rates were used, suggesting that mortality from all causes and all cancers in the cohort was not different from that in the region.

We found no excess of deaths from lung and bladder cancers, which have been related to occupational exposure to PAHs,[2] in agreement with other cohort studies among graphite electrode manufacturing workers.[3 4] Nor did we find increased mortality for cancers of the oral cavity and pharynx. Overall, mortality from cancers related to tobacco was in line with regional rates, suggesting that the prevalence of smoking in the cohort was similar to, or lower than in the general population. Recent data support this hypothesis: the proportion of smokers among workers exposed to PAHs at the factory (mean age 41 years) was 36% in 1994, lower than the 42% figure found among men of similar age and living in Central Italy in 1994.[18] The Poisson analysis showed a non-significant slightly increased risk of death from lung cancer with increasing time since first employment. However, the lack of an effect of duration of employment on risk of lung cancer argues against a carcinogenic risk.

We found an increased risk of death from stomach cancer by duration of employment. However, no overall increase in deaths from this cause was found in the whole cohort when compared with the national or regional population, and previous studies on carbon electrode production workers showed no increase in the ratio of observed to expected deaths from gastric cancer.[3–5]

Among other cancers, we found a higher than expected number of deaths from skin neoplasms, including melanoma, and testicular cancer. However, these findings are based on very few deaths, thus preventing any firm conclusion. The excess of deaths from testicular cancer is similar to that found among workers in one of the two plants examined by Moulin *et al* (SMR 5.66).[4]

The main finding of our study is the increased mortality for non-neoplastic respiratory diseases. An excess of pneumoconiosis has been reported among carbon electrode workers,[19 20] attributed mostly to silica and asbestos which are present in the work environment. Furthermore, graphite has also been reported as a cause of pneumoconiosis,[21] and cases of this disease have been described among graphite mine workers.[22] The excess of mortality for respiratory diseases in the cohort can not be attributed to tobacco smoking, as discussed previously. The excess of deaths from non-malignant diseases of the respiratory system may, at least partly, explain the lack of increased risk of death from respiratory tract

cancer, due to the mechanism of competitive causes of death.

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