Mortality in retired coke oven plant workers

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Abstract

A previous study on 536 retired coke oven plant workers in Lorraine Collieries (France) reported an excess of deaths from lung cancer (standardised mortality ratio (SMR) = 251) compared with the French male population. Occupational exposures during working life were retraced for each subject, but the number of deaths during the observation period (1963-82) was small, and smoking habits were known only for dead subjects. In 1988, the cohort was re-examined (182 deaths occurred between 1963 and 1987) and smoking habits were determined for all the subjects. This study confirmed the excess of lung cancer (SMR = 238, $p < 0.001$). It showed an excess of mortality from all causes (SMR = 141, $p < 0.001$), overall cancers (SMR = 133, $p < 0.05$), and cardiovascular diseases (SMR = 133, $p < 0.05$). A significant excess of deaths was found for subjects who worked near the ovens for all causes (145, $p < 0.01$), lung cancer (SMR = 252, $p < 0.01$), colon cancer (SMR = 381, $p < 0.05$), and cardiovascular diseases (SMR = 155, $p < 0.05$). A significant excess mortality was also found from all causes (176, $p < 0.05$) and stomach cancer (SMR = 538, $p < 0.01$) in subjects who worked in byproducts, from lung cancer (SMR = 433, $p < 0.001$) in those in the workshops, and from cirrhosis of the liver and alcoholism (SMR = 360, $p < 0.01$) in those underground; but, due to small numbers, these figures were not robust. An excess of mortality from all

causes (SMR = 163, $p < 0.01$), lung cancer (SMR = 228, $p < 0.05$), and cardiovascular diseases (SMR = 179, $p < 0.01$) was shown also for non-exposed or slightly exposed subjects. The fact that, on the whole, mortality of various exposed groups was similar to that of non-exposed or slightly exposed workers may be explained in part by the selection at hiring and the healthy worker effect. As an increased risk of lung cancer was noted among subjects who worked in the old generations of plant compared with the other workers (although the relative risk was not significant) it is concluded that the role of occupational hazards could not be excluded.

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The effect of occupational hazards in coke oven plants (notably of polycyclic aromatic hydrocarbon from the ovens, coal dusts, tar, etc) on mortality has been extensively investigated.¹⁻³⁰ A previous study carried out in 1983 on 536 retired workers from the two coke oven plants of Houillères du Bassin de Lorraine (Lorraine Collieries) reported a significant excess of mortality from lung cancer (SMR = 251, $p < 0.01$) with reference to the French male population.¹ The small number of deaths found during the observation period (1963-82) did not allow a full analysis of the effect of occupational exposures. Also, smoking habits were known only for dead subjects. In 1988, the cohort was re-examined, and smoking habits were determined for all the cohort members. A question of interest was whether there was an increased risk, notably for lung cancer, in the old generations of plant. In this study we analysed the effect of occupational hazards on subjects who worked on or near the ovens, but also on those in other exposed workplaces—namely, byproducts, workshops, and underground. All causes of death were studied, in particular various cancers and cardiovascular diseases.

Subjects who were still alive on 1 January 1988 (354 subjects) were asked to attend a medical examination at the firm's occupational health centre for a study on morbidity³¹ and on lung function.³²

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Materials and methods

In the Lorraine Collieries, coke is produced in two plants: plant A started production in 1911 (A_{old}) and plant B in 1955. The occupational hazards in plant A were reduced since the opening of A_{new} in 1963. The occupational exposure in B is considered as intermediate between A_{old} and A_{new} . The study population consisted of all the male manual workers from the two plants who had retired between 1 January 1963 and 31 December 1982; a total of 536 subjects (the date of entry in the study was that of retirement). They were born between 1902 and 1935. Seventy subjects (13.1%) worked in the old generations of plant A. Executives were excluded from the study. The observation period ranged from 1 January 1963 to 31 December 1987 (25 years). During this period, 182 deaths occurred (34.0%).

Causes of death have been established from the medical records kept by hospitals, occupational physicians, general practitioners, and physicians from the health services. In this study, only the main cause of death was considered; it was coded according to the 9th revision of the International Classification of Diseases.³³ These records allowed us also to define the smoking habit for each subject. Information gathered from the subject himself and his family enabled us to complete and confirm data from medical records. Because of lack of precision and small numbers, we did not differentiate between the various categories of smokers or distinguish between smokers and ex-smokers.

OCCUPATIONAL EXPOSURES

For each subject, the job history was retraced to define the occupational hazards during his working life. The job history was broken down into a succession of occupations, for each of which were defined the date of the beginning and the end of each occupation, the job, the workplace, and the occupational nuisances. The analysis of the jobs held during a career showed that almost all of the subjects had one dominant job. This led us to define six types of homogeneous exposure with each subject being classified in the exposure group that corresponded to the longest duration of exposure when this period equalled or exceeded five years. The six were:^{1 32}

(1) Constant presence on the coke ovens (noted ovens): support setter, shield setter, oven regulator, door cleaner, column cleaner, and tar cleaning tube operator.

(2) Activity near the ovens and intermittent presence on the ovens (noted N ovens): pusher machine operator, stamper, switch operator, coke car, maintenance personnel on the ovens, fitter.

(3) Exposure in repair and maintenance workshops (noted workshops).

(4) Exposure to byproducts (noted byproducts) in

the oven gas treatment sector: benzol, phenol, sulphates, pitch, tars, etc.

(5) Underground work in coalmines (noted underground).

(6) Non- or slightly exposed (noted non-exposed): administrative personnel, time keeper, maintenance personnel who did not come into direct contact with the ovens, coal mixing work, porter, etc.

STATISTICAL METHODS USED

The statistical analysis consisted mainly in comparing each exposed group with the non-exposed group. Comparison of the subjects' age was made by analysis of variance and that of smoking with χ^2 independence test or Fisher's exact probability test.^{34 35} The mortality analysis was made using the standardised mortality ratio (SMR) (%)³⁶⁻³⁸ with the French male population as standard population.³⁹ The SMRs were calculated with five year age groups, for each year of the observation period. Comparison of mortality between the two plants was made with the homogeneity χ^2 test of SMRs.^{36 38} To assess the risk of an exposed group *v* the non-exposed one we calculated the relative risk (ratio of SMRs) when these SMRs were significant. To estimate the effect of the old generations of plant A on lung cancer the relative risk was also calculated, differentiating two categories of workers: subjects who worked only in the plant A_{new} and those who worked in A_{old} . All the statistical tests were carried out with a first order risk of 0.05 excluding the non-responses. The different statistical analyses were made with the Logist program.⁴⁰

Results

The study population consisted of 536 retirees. During the study period 182 deaths occurred (34.0%). Table 1 presents the characteristics of the occupational exposure groups. The total duration of exposure ranged from 18 to 24 years. The non-exposed subjects had an average total duration of exposure of 1.2 years. Smoking for each exposed group was similar to that of the non-exposed group. The mean age at death was 64.8 years. The subjects of the underground group had an age at death lower than that of the other groups and they entered the study younger.

The main causes of death were cardiovascular diseases (35.2%) and cancers (33.0%). Lung cancer was the cause in 13.7% of the cases, cirrhosis of the liver and alcoholism in 7.1%, and respiratory diseases in 4.9%. Each of the other causes accounted for less than 3% of cases. The frequency of unknown causes (11.0%; table 2) was close to the figure of the national statistics.

For all the cohort, a significant excess mortality (in reference to the French male population) was found for all causes (SMR = 141, $p < 0.01$), cardio-

Table 1 Characteristics of occupational exposure groups

	Group						
	Total	Non-exposed	Ovens	N ovens	Workshops	Byproducts	Underground
All the cohort							
No of subjects	536	126	65	165	61	42	77
Smoking (% of subjects):							
Non-smokers	22.6	22.2	24.6	22.4	24.6	26.2	18.2
Smokers	64.2	66.7	66.2	64.9	67.2	45.3	65.0
Unknown	13.2	11.1	9.2	12.7	8.2	28.6	16.9
Duration of different types of exposure (mean (SD) (y)):							
Ovens	1.8 (5.0)	0.1 (0.5)	14.0 (5.9)	0.3 (0.9)	—	0.07 (0.4)	0.1 (0.6)
N ovens	5.2 (8.7)	0.2 (0.7)	2.7 (5.6)	15.6 (8.6)	0.1 (0.6)	—	0.3 (1.1)
Workshops	3.7 (8.1)	0.2 (0.7)	2.2 (5.9)	3.0 (6.7)	20.7 (8.8)	0.8 (3.2)	0.3 (1.0)
Byproducts	2.1 (7.2)	0.1 (0.7)	0.1 (0.7)	1.0 (4.4)	0.4 (2.1)	22.1 (11.8)	0.02 (0.1)
Underground	4.2 (7.4)	0.6 (1.2)	3.7 (7.2)	3.2 (5.8)	0.7 (1.8)	1.0 (2.1)	17.4 (6.8)
All types combined	17.1 (12.1)	1.2 (1.7)	22.7 (8.9)	23.0 (9.5)	21.9 (9.0)	24.0 (11.8)	18.2 (7.2)
Dead subjects							
No of deaths	182	54	17	56	15	18	22
Age at death (mean (SD) (y))	64.8 (7.3)	65.2 (7.1)	64.1 (5.8)	66.4 (6.7)	64.7 (7.2)	64.3 (8.1)	60.7 (8.6)*

*p < 0.05, comparison of means and homogeneity test between each exposed group and the non-exposed group (all the smokers were grouped together; unknown responses were excluded).

vascular diseases (SMR = 133, p < 0.05), overall cancers (SMR = 133, p < 0.05), and especially lung cancer (SMR = 238, p < 0.01). Other cancers (upper respiratory and alimentary tract, oesophagus, stomach, bladder, etc) were under-represented (table 3).

An excess of overall mortality was seen for all groups but it was significant only for subjects who worked near the ovens (SMR = 145, p < 0.01), in byproducts (SMR = 176, p < 0.05), and also for

non-exposed workers (SMR = 163, p < 0.001). Mortality from overall cancer was also higher than expected for all groups but the excess was not significant. The SMR for lung cancer was above 100 for all groups except the underground group, but it was significant only for workers near the ovens (252, p < 0.01), in the workshops (433, p < 0.001), and non-exposed (228, p < 0.05). Compared with non-exposed subjects, those near the ovens and those in the workshops had a relative risk for lung cancer of

Table 2 Distribution of causes of death (%)

Cause of death (ICD-9)	Total	Group					
		Non-exposed	Ovens	N ovens	Workshops	Byproducts	Underground
No of subjects	182	54	17	56	15	18	22
Cancer, all sites (140-239)	33.0	24.1	47.1	32.1	66.7	27.8	27.3
Lung (162)	13.7	11.1	11.8	14.3	40.0*	11.1	4.5
Upper respiratory tract, alimentary tract (140-149, 161)	2.2	1.8	5.9	1.8	6.7	—	—
Oesophagus (150)	1.6	3.7	5.9	—	—	—	—
Stomach (151)	2.2	—	5.9	—	—	11.1	4.5
Bladder (188)	0.5	—	—	1.8	—	—	—
Colon (153)	2.2	—	—	5.4	—	—	4.5
Rectum (154)	0.5	—	—	1.8	—	—	—
Haemopathies (200-209)	1.1	—	5.9	—	6.7	—	—
Other sites	8.8	7.4	11.8	7.1	13.3	5.6	13.6
Infectious diseases (000-139)	1.6	—	—	1.8	—	5.6	—
Cardiovascular diseases (390-459)	35.2	42.6	35.3	39.3	13.3	22.2	31.8
Respiratory diseases (460-519)	4.9	7.4	—	8.9	—	—	—
Cirrhosis of liver, alcoholism (571.0-3,5)	7.1	3.7	11.8	3.6	13.3	5.6	18.2
Other digestive tract diseases	1.7	1.8	—	1.8	—	5.6	—
Accidents, other violence (E800-999)	2.8	3.7	—	1.8	—	—	9.1
Other causes	1.6	3.7	—	—	—	5.6	—
Undefined causes	1.1	—	5.9	—	—	—	4.5
Unknown causes	11.0	11.1	—	10.7	6.7	27.8	9.1
All causes	100.0	100.0	100.0	100.0	100.0	100.0	100.0

*p < 0.01, comparison of frequencies between each exposed group and the non-exposed group.

Table 3 Mortality according to occupational exposure

Cause of death (ICD-9)	Group													
	Total		Non-exposed		Ovens		N ovens		Workshops		Byproducts		Underground	
	O	SMR	O	SMR	O	SMR	O	SMR	O	SMR	O	SMR	O	SMR
All causes	182	141***	54	163***	17	132	56	145**	15	87	18	176*	22	130
Cancer, all sites (140-239)	60	133*	13	114	8	168	18	133	10	166	5	138	6	103
Lung (162)	25	238***	6	228*	2	175	8	252**(a)	6	433*** (b)	2	237	1	74
Upper respiratory and alimentary tract (140-149, 161)	4	64	1	66	1	146	1	53	1	126	—	(0.49)	—	(0.85)
Oesophagus (150)	3	90	2	242	1	283	—	(1.01)	—	(0.43)	—	(0.27)	—	(0.44)
Stomach (151)	4	91	—	(1.19)	1	227	—	(1.31)	—	(0.59)	2	538**	1	197
Bladder (188)	1	70	—	(0.37)	—	(0.14)	1	237	—	(0.19)	—	(0.11)	—	(0.18)
Colon (153)	4	151	—	(0.68)	—	(0.27)	3	381*	—	(0.36)	—	(0.21)	1	301
Rectum (154)	1	71	—	(0.37)	—	(0.14)	1	238	—	(0.19)	—	(0.11)	—	(0.18)
Cardiovascular diseases (390-459)	64	133*	23	179**	6	123	22	155*	2	30	4	100	7	124
Respiratory diseases (460-519)	6	68	4	171	—	(0.89)	2	77	—	(1.22)	—	(0.73)	—	(1.03)
Cirrhosis of liver, alcoholism (571-0-3,5)	13	137	2	82	2	192	2	70	2	160	1	124	4	360**
Accidents, other violence (E800-999)	5	54	2	86	—	(0.96)	1	36	—	(1.20)	—	(0.74)	2	153

*p < 0.05; **p < 0.01; ***p < 0.001.

O = Number of observed deaths. When O equals zero, the number of expected deaths is given in parentheses.

(a) Relative risk compared with the non-exposed group (RR = ratio of SMRs) = 1.11, NS; (b) RR = 1.90, NS.

1.11 (NS) and 1.90 (NS) respectively. This study showed a significant SMR for stomach cancer for men in byproducts (538, $p < 0.01$), for colon cancer for those near the ovens (381, $p < 0.05$), for cardiovascular diseases for non-exposed workers and those near the ovens (179, $p < 0.01$ and 155, $p < 0.05$ respectively), and for cirrhosis of the liver and alcoholism for men working underground (360, $p < 0.01$) (table 3).

Tables 4 and 5 show the effect of smoking for each exposure group. Because of small numbers, workers on and those near the ovens were grouped together

for each type of cancer. Firstly, although the frequency of subjects with unknown smoking habits was low (13.2%), it was easier to determine the smoking habits for survivors than for dead subjects (7.9% v 23.6%, $p < 0.001$). Thus mortality of smokers and non-smokers may be underestimated. For all causes, although the smokers had a significant SMR ($p < 0.01$) and the non-smokers a non-significant SMR, their SMRs were close (130 v 127 respectively). A significant excess of all cancers was found only for smokers (SMR = 150, $p < 0.01$); this was due to the men working on the ovens

Table 4 Mortality according to occupational exposure and smoking

Cause of death (ICD-9)	Group													
	Total		Non-exposed		Ovens		N ovens		Workshops		Byproducts		Underground	
	O	SMR	O	SMR	O	SMR	O	SMR	O	SMR	O	SMR	O	SMR
All causes:														
Non-smokers	40	127	11	136	4	120	12	140	6	128	4	129	3	81
Smokers	99	130**	33	155*	12	151	31	133	7	68	5	119	11	116
Unknown	43	205***	10	271**	1	61	13	198*	2	84	9	307***	8	213*
Cancer, all sites (140-239):														
Non-smokers	11	99	1	35	1	82	2	65	3	193	3	275(a)	1	77
Smokers	41	150**	10	137	7	239*	12	141	6	164	2	128	4	118
Unknown	8	118	2	164	—	(0.62)	4	199	1	126	—	(0.97)	1	87
Cardiovascular diseases (390-459):														
Non-smokers	20	166*	8	235*	2	172	7	224*	2	119	—	(1.28)	1	71
Smokers	35	121	14	169*	3	102	12	134	—	(3.99)	2	114	4	131
Unknown	9	127	1	85	1	132	3	145	—	(0.96)	2	205	2	174
Cirrhosis of liver, alcoholism (571-0-3,5):														
Non-smokers	2	84	—	(0.67)	1	398	—	(0.64)	1	349	—	(0.25)	—	(0.27)
Smokers	9	151	2	129	1	160	2	104	1	124	1	260	2	298
Unknown	2	169	—	(0.21)	—	(0.16)	—	(0.32)	—	(0.15)	—	(0.17)	2	1193***

*p < 0.05; **p < 0.01; ***p < 0.001; (a) p < 0.09.

O = Number of observed deaths. When O equals zero, the number of expected deaths is given in parentheses.

Table 5 Mortality from some cancers according to occupational exposure and smoking

Cause of death (ICD-9)	Group												
	Total		Non-exposed		Ovens	+	N ovens	Workshops		Byproducts		Underground	
	O	SMR	O	SMR	O		SMR	O	SMR	O	SMR	O	SMR
Lung cancer (162):													
Non-smokers	1	39	—	(0.66)	—		(1.01)	1	166	0	0	—	(0.30)
Smokers	20	310***	5	297*	8		294** ^(a)	5	581*** ^(b)	1	268	—	(0.50)
Unknown	4	265*	1	360	2		345	1	560	—	(0.22)	—	(0.25)
Upper respiratory and alimentary tract cancer (140–149, 161):													
Non-smokers	—	(1.51)	—	(0.39)	—		(0.61)	—	(0.19)	—	(0.14)	—	(0.18)
Smokers	3	78	—	(0.97)	2		122	1	196	—	(0.23)	—	(0.53)
Unknown	1	114	1	620*	—		(0.35)	—	(0.22)	—	(0.13)	—	(0.15)
Oesophageal cancer (150):													
Non-smokers	—	(0.81)	—	(0.21)	—		(0.32)	—	(0.11)	—	(0.08)	—	(0.09)
Smokers	3	148	1	381	1		119	—	(0.27)	—	(0.12)	—	(0.26)
Unknown	—	(0.48)	—	(0.09)	—		(0.19)	—	(0.05)	—	(0.07)	—	(0.08)
Stomach cancer (151):													
Non-smokers	3	268	—	(0.32)	1		250	—	(0.15)	2	1676***	—	(0.13)
Smokers	—	(2.64)	—	(0.75)	—		(1.09)	—	(0.36)	—	(0.16)	—	(0.28)
Unknown	1	152	—	(0.12)	—		(0.26)	—	(0.09)	—	(0.09)	1	969**
Colon and rectum cancer (153–154):													
Non-smokers	—	(1.02)	—	(0.26)	—		(0.38)	—	(0.15)	—	(0.11)	—	(0.12)
Smokers	4	168	—	(0.67)	3		306*	—	(0.32)	—	(0.15)	1	369
Unknown	1	152	—	(0.12)	—		385	—	(0.08)	—	(0.09)	—	(0.11)

*p < 0.05; **p < 0.01; ***p < 0.001.

O = Number of observed deaths. When O equals zero, the number of expected deaths is given in parentheses.

Relative risk (ratio of SMRs) compared with unexposed group; (a) = 0.99 (NS); (b) = 1.96 (NS).

(SMR = 239, p < 0.05). For cardiovascular diseases, a significant SMR was found only for non-smokers (166, p < 0.05). The excess of stomach cancers for men in byproducts was also only found for non-smokers (1676, p < 0.001).

For lung cancer, non-smokers did not have a significant excess of deaths. For smokers (SMR = 310, p < 0.001) a significant SMR was found for workers on or near the ovens (294, p < 0.01), in the workshops (581, p < 0.001), and in the non-exposed workers (297, p < 0.05). Compared with the non-exposed subjects, workers on or near the ovens and those in the workshops had relative risks of 0.99 and 1.96 (NS) respectively. For

each exposure group, smokers and subjects having unknown smoking habits had similar SMRs.

The excess of mortality from lung cancer was greater among subjects who worked in plant A than among those in plant B but the difference was not significant. The excess of all cancers was significant only for plant B (SMR = 157, p < 0.05). Conversely, mortality from cirrhosis of the liver and alcoholism was only increased for plant A (SMR = 190, p < 0.05; table 6). An interesting question was whether there was an increased risk of lung cancer among the subjects who worked at the beginning of their careers in A_{old} where the level of exposure to polycyclic aromatic hydrocarbons could

Table 6 Mortality according to plants

Cause of death (ICD-9)	Plant A		Plant B		Test
	O	SMR	O	SMR	
All causes	101	134**	81	152***	NS
Cancer, all sites (140-239)	30	115	30	157*	NS
Lung (162)	16	267***	9	199*	
Upper respiratory tract, alimentary tract (140-149, 161)	1	29	3	109	
Oesophagus (150)	—	(1.89)	3	210	
Stomach (151)	2	79	2	107	
Bladder (188)	—	(0.83)	1	171	
Colon (153)	1	64	3	274(a)	
Rectum (154)	—	(0.83)	1	172	
Cardiovascular diseases (390-459)	36	129	28	139(a)	
Respiratory diseases (460-519)	2	39	4	109	
Cirrhosis of liver, alcoholism (571.0-3,5)	10	190*	3	71	
Accidents, other violence (E800-999)	3	56	2	50	

*p < 0.05; **p < 0.01; ***p < 0.001; (a)p = 0.08.

O = Number of observed deaths. When O equals zero, the number of expected deaths is given in parentheses.

Table 7 Comparison of mortality from all causes and from lung cancer between subjects having worked and those who did not work in the old generations of plant A

	No of subjects	Lung cancer							
		All causes		Total		Ovens + N ovens		Other groups	
		O	SMR	O	SMR	O	SMR	O	SMR
Subjects who worked only in plant A _{new} :									
Non-smokers	102	30	117	—	(2.11)	—	(0.69)	—	(1.42)
Smokers	296	85	121	16	218**	5	236*	11	315***
Unknown	68	41	225***	4	294*	2	455*	2	218
Total (1)	466	156	147***	20	229***	7	215*	13	237**
Subjects having worked in A _{old} :									
Non-smokers	19	10	168	1	213	—	(0.32)	1	966***
Smokers	48	14	96	4	342**	3	495**	1	177
Unknown	3	2	72	—	(0.14)	—	(0.14)	—	—
Total (2)	70	26	112	5	281*	3	282(a)	2	622***
Relative risk (ratio of SMRs of totals (1) and (2))					1.23	1.31		2.89	
95% CI								(0.42–15)	

*p < 0.05; **p < 0.01; ***p < 0.001; (a)p = 0.06.

O = Number of observed deaths. When O equals zero, the number of expected deaths is given in parentheses.

have been higher than in A_{new}. Table 7 presents the comparative results between the subjects who worked in A_{old} and the other workers. Unexpectedly the subjects who worked in A_{old} had a non-significant SMR for all causes (112) whereas those who worked only in A_{new} had a significant SMR (147, p < 0.001). For lung cancer, compared with the subjects who worked only in A_{new}, those who worked in A_{old} had a relative risk greater than unity (1.31 for subjects on or near the ovens, 2.89 for the other subjects, and 1.23 for all groups together) but this was not significant. Compared with the subjects who worked only in A_{new}, those who worked in A_{old} for more than five years had a relative risk for lung cancer of 1.10 (NS) for men on or near the ovens, 4.31 (p = 0.06, 95% CI = 0.59–22.00) for the other workers, and 1.46 (NS) for all groups together.

Discussion

The reconstitution of each subject's job history enabled us to define his occupational exposure during his working life. Almost all subjects had one dominant job and the six exposure categories were homogeneous. The total duration of exposure ranged from 18 to 24 years. The non-exposed group also included slightly exposed subjects; they had an average total duration of exposure of 1.2 years. The frequency of unknown causes of death (11.0%) was close to that of the French male population used as the standard population.

Smoking habits were determined for 86.8% of the subjects. Because of small numbers, we did not distinguish between smokers and ex-smokers. This is a weakness that stems from the fact that the frequency of subjects having unknown smoking was significantly higher in dead subjects than in survivors

(23.6% v 7.9%, p < 0.001). Thus the mortality of non-smokers and smokers may be underestimated. This bias may conceal in part the effect of occupational exposures.

The choice of the standard population was important. We were tempted to choose the population of Lorraine (1.16 million men in 1975⁴¹) or, better, that of the administrative division of Moselle (0.51 million men in 1975⁴¹) because the mortality from lung cancer is higher in these regions compared with that of France (SMR 140 for Lorraine and 159 for Moselle in the 1971–78 period⁴¹). Unfortunately, the statistics for these areas are not available for the years 1963–74. Pursuing this logic, however, the most appropriate standard population was that of the coalmine district as this region was exposed to fairly high atmospheric pollution produced by the industrial platforms.⁴² Unexpectedly, this area has, for 1980–1984, an SMR for lung cancer equal to that of all Lorraine⁴³ but these figures concern a period different from that of the present study.

Although the phenomenon of lower mortality in working populations,^{3,28} the healthy worker effect, is frequently reported, our study showed a total mortality higher than expected (SMR = 141, p < 0.001). This excess mortality was found among subjects who worked near the ovens (145, p < 0.01) and in byproducts (176, p < 0.05), but also among non-exposed workers (SMR = 163, p < 0.001). In the previous study¹ the excess of overall mortality was small (SMR = 107) and non-significant. The increase in the death rate found in the five year interval allowed us to consider that the deterioration in health of the study retirees compared with a normal population was accelerated with age. Increasing mortality was found for several causes, however, (especially for cardiovascular diseases (SMR = 133, p < 0.05)) whereas the SMR for lung cancer did not

vary (251 v 238). This seemed to show that in the retirees the competing risk may change with age. It is interesting that the age at death varied slightly with the cause: 63.3 (SD 1.4) years for lung cancer, 63.5 (SD 1.0) years for other cancers, 66.4 (SD 0.8) for cardiovascular diseases, and 64.5 (SD 1.1) for other causes; the difference between overall cancer and cardiovascular diseases was significant ($p < 0.05$). Consequently, the age of the subjects may explain in part the differences between these results and those of other investigators.

An excess of mortality from lung cancer was found for all exposure groups except for those working underground; but probably due to small numbers, it was significant only for subjects who worked near the ovens (SMR = 252, $p < 0.01$), in the workshops (SMR = 433, $p < 0.001$) and in non-exposed workers (SMR = 228, $p < 0.05$). This investigation confirmed that the excess of deaths from lung cancer was slightly higher in plant A than in plant B, but the difference was not significant. Compared with the subjects who worked only in A_{new}, those who worked in A_{old} had a relative risk for lung cancer higher than unity but it was not significant. Regarding mortality in Lorraine, the excess of lung cancer could not be explained solely by the regional factor.

The proportion of smokers in the study population (74%; subjects with unknown smoking habits excluded) was slightly lower than that in the French male population (about 80%).⁴⁴ A question of interest was whether this difference could explain the increased value of SMR for lung cancer. Using the method proposed by Axelson and Steenland⁴⁵ and suggested by Moulin,⁴⁶ and assuming a risk for lung cancer equal to unity for non-smokers and up to 10 for smokers (these values were close to those habitually exposed),⁴⁷ the relative risk of the study population was close to unity compared with the French male population. On the other hand, in the present study, mortality from upper respiratory and alimentary tract cancer, usually attributed to smoking, was low (SMR = 64) even for smokers (SMR = 78).

A significant excess of deaths from stomach cancer was found for workers in byproducts (SMR = 538, $p < 0.01$), from colon cancer for those near the ovens (SMR = 381, $p < 0.05$), and from cirrhosis of the liver and alcoholism for those underground (SMR = 460, $p < 0.01$), but, due to small numbers, these figures were not robust. The increased risk for cardiovascular diseases was significant for workers near the ovens (SMR = 155, $p < 0.05$) but also for non-exposed subjects (SMR = 179, $p < 0.01$).

The increased values of the SMRs for all causes of death, lung cancer, and cardiovascular diseases could be explained in part by the fact that the study subjects were unskilled workmen. Indeed, they had a life expectancy lower than that of the French male

population.⁴⁸ For the same number of deaths, the value of the SMR is higher when the deaths intervene earlier. This factor could not totally explain the excess mortality, however, because the value of the SMR varied greatly with the cause of death, and the highest value was found for lung cancer.

Comparison with the results of other investigations is difficult because of the differences in the choice of the study population and of the standard population, the nature and the level of the hazards, which could change with time,⁷ the healthy worker effect, the socioeconomic state of the workers, the method of data collection, etc. The concentration of polycyclic aromatic hydrocarbons was higher for the American coke ovens than for those in Europe.²⁹ Also, there were racial differences among the workers. For example, the American coke ovens were mainly operated by non-white workers. On the other hand, there were also further hazards such as heat, coal dust, and work conditions. In this investigation, the study subjects were exposed, moreover to atmospheric pollution at their workplace and sometimes at their home, which was often near the Carling or Marienau industrial platforms.⁴²

Kennaway and Kennaway¹³ found, for coke oven workers in England and Wales from 1921 to 1938, a death rate from lung cancer 2.8 times and from laryngeal cancer 2.1 times higher than expected in reference to the general population. In 1972 Doll *et al*⁴ noted that among 4700 coal gasification workers in Great Britain, the subjects with the highest exposure had a risk higher than the general population for bladder cancer, scrotal and skin cancer, lung cancer, and bronchitis. Davies³ stated that among 610 coke plant workers overall mortality was lower than expected and no excess of deaths from cancer was found. In 1977, Jacobsen and Hurley¹⁰ found a death rate of lung cancer 29% higher than expected among 4836 men in the British industries of coal carbonisation and tar distillation. This difference was significant but there were important variations between various plants. Recently, in a study on 6673 coke workers employed in 1967 in 27 plants throughout Britain, Hurley *et al*⁷ found an excess of mortality from lung cancer that was related to estimates of exposure of workers to concentrations of benzene soluble materials up to 1967. They reported a significant association between stomach cancer and the time worked in byproducts. Thus this result supports our finding. Recently, these authors⁸ reported that excess of mortality from leukaemia had not been identified among coke oven and other coal product workers. In our study, two deaths occurred from this cause.

In 1991, Swaen *et al*²⁹ reported the results of a mortality study in the Netherlands of 5639 subjects who had worked in a coke plant for more than six months between 1945 and 1969 compared with 5740 who had worked in a nitrogen fixation plant during

the same period. These authors found a death rate of lung cancer and of non-malignant respiratory diseases significantly higher than expected among the coke oven workers, but the workers in byproducts had a mortality similar to that expected. They also found the highest overall mortality for subjects who worked in the oldest plant (started in 1918). In our investigation, an increased risk for lung cancer was shown in the former generations of the plant A, although it was not significant.

It was interesting to enlarge the comparison to an investigation by Pham *et al*⁴⁹ on mortality in 13 801 iron miners in the same Lorraine area (this eliminates the ethnic problem) between 1982 and 1986. These authors found that among smokers, in reference to the French male population, a proportionate mortality ratio (PMR) for lung cancer was linked to the duration of underground work (2.04 for 1–19 years, 2.32 for 20–29, and 3.05 for ≥ 30 years), but the differences were not significant. They reported a significant PMR (2.31) for stomach cancer, but this did not vary significantly with the duration of underground work. As in our investigation, these authors also found a mortality from upper respiratory and alimentary tract cancer lower than expected for smokers.

In the United States, Lloyd¹⁵ reported a mortality from lung cancer 2.5 times higher for workers on ovens of the Alleghany County coke ovens plants, than for other steelworkers. Redmond *et al*¹⁷ showed that the death rate from lung cancer was linked to duration and amount of exposure while working on the ovens: the death rates of lung cancer were respectively 2.5 and 3.5 times higher than expected for men employed on the ovens and for those at the work place for more than five years. Also, the relative risk for lung cancer was 2.1 times higher for men working only near the ovens, 3.2 for those on and near, and 6.9 for those on the ovens. In 1979, Redmond *et al*¹⁸ reported that non-white coke oven workers had a risk for lung cancer twice higher than other steelworkers, and that the risk was eight times higher for men working on the ovens.

In Japan, Kawai *et al*¹² reported a higher mortality from lung cancer than expected among workers of a coal gasification plant. Sakabe *et al*²⁸ found, for 4655 retired employees from 36 steelworks, a mortality from all cancer sites and from lung cancer similar to that of the general population; none the less, among workers from coke oven plants, mortality from lung cancer was twice as high as expected.

Finally, despite several unknown factors (healthy worker effect, selection at hiring, etc), the results obtained in this study seem to show that the role of occupational hazards could not be excluded. The effect of hazards in the old generations of plant could be clarified if the cohort were followed up for a few more years.

Conclusion

This study showed a significant excess of deaths from all causes, all cancers, and cardiovascular diseases, whereas for lung cancer the SMR did not change compared with that in the previous study. A significant excess mortality was found for all causes, lung cancer, colon cancer, and cardiovascular diseases for subjects who worked near the ovens. This investigation shows that the ovens were not the only exposed work places. A significant excess mortality was also found for subjects who worked in byproducts for all causes and stomach cancer, for those in the workshops for lung cancer, and for those underground for cirrhosis of the liver and alcoholism. An excess of deaths from all causes, lung cancer, and cardiovascular diseases was, however, also found, for non-exposed or slightly exposed subjects. The fact that on the whole the mortality of various exposed groups was similar to that of non-exposed or slightly exposed workers may be explained in part by the selection at hiring and the healthy worker effect. As an increased risk of lung cancer was noted among subjects who worked in the old generations of plant compared with the other workers (although the relative risk was not significant) we concluded that the role of occupational hazards could not be excluded. A directive of 28 July 1990 of the Council of the European Community⁵⁰ gives measures to fight such occupational hazards.

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