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Mortality due to respiratory cancers in the coke oven plants of the Lorraine coalmining industry (Houillères du Bassin de Lorraine)

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ABSTRACT The main activity of the Houillères du Bassin de Lorraine (Lorraine Collieries), employing 23 000 operatives and executives, is coalmining. The coke production is carried out by two coke oven plants with a workforce of respectively 747 and 552 workers. The coal coking process entails the emission of noxious products such as polycyclic aromatic hydrocarbons (PAH) from the ovens. The influence of occupational exposure on mortality due to respiratory cancers, and particularly to lung and upper respiratory and alimentary tracts cancer, was investigated among a cohort of 534 male workers from the two coke oven plants who had retired from work between 1963 and 1982. The job history of each subject has been precisely reconstructed by indicating the duration of exposure on the ovens, close to the ovens, and in maintenance occupations. The cohort mortality has been analysed according to the method of indirect standardisation with reference to the French male population and by a case-control study concerning the consumption of tobacco per cohort. The mortality due to lung cancer is 2·51 times higher than expected. This excess of mortality differs, but not significantly, between the two coke oven plants (standardised mortality ratio equals 3·05 and 1·75 respectively). It is not significantly higher among subjects exposed for more than five years, directly exposed on the ovens or working near the ovens or at maintenance occupations on the ovens (SMR = 2·78), than among those exposed for less than five years (SMR = 2·35) or those not exposed at all. Even taking into account the excess of mortality due to lung cancers in the Moselle district (1·6 time that of France), the excess of lung cancers does not seem to be explained by the regional factor, or by tobacco and alcohol consumption. Although no significant relation was offered between lung cancer and the duration of exposure to PAH, even when taking smoking habits into account, the carcinogenic role of occupational nuisances cannot be excluded.

The Lorraine Collieries (Houillères du Bassin de Lorraine) have a workforce of 23 000 employees. Coke is produced in two coke oven plants (A and B) with 747 employees in plant A and 552 in B. Plant A was the cradle of carbonisation as it was started in 1911; numerous extensions and new processes were set up there. The occupational hazards of coke production were reduced by the starting of A–III in 1963 thanks to the development of the stamping technique; this method consists of stamping the blend before charging it into the oven; the coal blend is then heated to 1350°C for 18 hours. Plant B was set into operation in 1955: there are 158 ovens, in six batteries, comprising three stamping charging-discharging machines. The nuisances in B may be considered as intermediate between the two above mentioned generations of A plant.

The coal coking process produces noxious volatile matters, whose toxicity is linked to the emission of

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polycyclic aromatic hydrocarbons (PAH), amounting to 2% or 3% of the particulate weight and ranging between 3% and 6% of the benzene soluble fraction.[1] The risk of cancer linked to exposure to tar and PAH has been repeatedly investigated.[2-23]

The present study investigated the influence of this occupational exposure on mortality from lung cancer and upper respiratory and alimentary tract cancer (URAC) among workers who have constantly worked on the ovens or near ovens and among maintenance workers with intermittent exposure on the ovens. Smoking habits, another potential factor of lung cancer, were taken into consideration.

Material and methods

POPULATION

The population investigated was a cohort of male manual workers from the coke oven plants A and B who had retired from working in the coke oven plants after 1 January 1963. They were born between 1902 and 1935. The period of investigation ranged from 1 January 1963 to 31 December 1982.

Table 1 shows the age distribution of the study population. The number of employees is a little higher in plant A than in plant B. Nineteen per cent of the cohort have died. Causes of death have been established from the medical records kept in hospitals or by occupational physicians, by general practitioners, and by physicians from the health services. We looked for the main and the secondary causes of death, the pathological elements known in the subject's life, the reasons for admission to hospital, alcohol consumption, and smoking habits. Information gathered from the subject's relatives enabled us to complete and confirm the data recorded in the medical records.

Each subject's job history has been compiled from the personnel work and health descriptions noted in the administrative records and the occupational medical record. For this, we had to rely on the contributions of the foremen. It consisted of breaking down the job history into a series of occupations for which we had to define:

The workplace—A distinction was made between occupations in each coke oven plant but also outside coke oven plants: in a power plant, in the chemical industry, underground, in other typical mining activities, and in administrative jobs.

Table 1 *Distribution of the study population*

	Plant A	*Plant B*	*Total*
Living	229	201	430
Dead	60	44	104
Total	289	245	534

Type of occupational nuisances—coal dust, other particles, paint, welding, gas, smokes, benzene, phenol, sulphates, pitch, and tars.

The aim of the study was to analyse the risk of cancer linked to the exposure to the specific nuisances of coke oven plants, categorised according to task:

Exposure on the ovens—Support setter, shield setter, oven regulator, door cleaner, column cleaner, tar cleaning tube operator.

Exposure near the ovens—Pusher machine operator, stamper, switch operator, coke car, etc ....

Intermittent exposure on ovens—Maintenance personnel on ovens, fitter, electrician, maintenance worker, fireproof bricklayer, etc. ....

These three categories are characterised by the degree of exposure to dust, gas, and fumes. Maintenance personnel who are not in direct contact with the ovens, and occupations with no direct exposure to dust, gas, and fumes are considered as not or slightly exposed. This last category also comprises those working at the revolving kiln, a process generating few harmful pollutants.

STATISTICAL METHODS USED

The study of the cohort mortality has been conducted with the national male population as a reference (statistics of INSERM[24] and INSEE[25]). The method of indirect standardisation consists in calculating the expected number of deaths by applying the reference mortality to the age groups of the cohort, for each year, from 1963 to 1982[26]; from the observed (O) and expected (E) numbers of deaths the standardised mortality ratio (SMR) may be calculated.[27-30]

We have tested the null hypothesis, Ho: "the cohort mortality is equal to the reference population mortality" considering that O follows a Poisson distribution with E as a parameter (bilateral test).[26]

A comparison of the mortality in several subgroups—for example, comparison of mortalities between the two cokeries or between groups of occupational exposure—was conducted according to the homogeneity chi-square test of the corresponding SMR.[26]

To evaluate the influence of occupational exposure on lung cancer mortality, it is important to take smoking habits into account. Case control analysis of deaths from lung cancer is included in the cohort study. For each death due to lung cancer, we chose two controls who had died from a cause other than respiratory cancer. The matching criteria were year of birth, age at death, and smoking habits. The exposures to dust, gas, and fumes of the cases and the controls were compared by means of two methods:

(1) the distribution by categories of duration of exposure (less than five years, from five to nine years, and 10 years and more) were compared by means of

Table 2 *Distribution of dead subjects according to age and main cause of death. CIM codes, 9th rev,[34] are indicated in parentheses*

Main causes of death	*Age at death (years)* ⩽54	55–64	⩾65	*Total*
Total No of cancers (140–209)	2	23	10	35
Infectious diseases (000–139)	—	1	1	2
Cardiovascular causes (390–459)	—	21	15	36
Respiratory diseases (460–519)	1	1	1	3
Cirrhosis and alcoholism (303, 571–0)	5	4	1	10
Accidents and other violence (E800–E999)	—	3	1	4
Other causes	—	2	1	3
Undefined, unknown causes (780–799)	2	4	5	11
All causes	10	59	35	104

Table 3 *Distribution of cancers by site. CIM codes, 9th rev,[34] are indicated in parentheses*

Main cause of death	*Age at death (years)* ⩽54	55–64	⩾65	*Total*
Lung (162)	1	12	4	17
URAC (140–149, 160–161)	—	2	—	2
Oesophagus (150)	—	—	1	1
Stomach (151)	—	2	2	4
Intestines (152)	—	2	2	4
Pancreas (157)	—	2	—	2
Genitourinary tract cancer (180–189)	—	—	1	1
Haemopathies (200–209)	—	1	—	1
Other cancers	1	2	—	3
Total No of cancers (140–209)	2	23	10	35

URAC: Upper respiratory and alimentary tract cancer.

Armitage's statistical test of homogeneity of proportions[31];

(2) the differences in individual exposures were analysed by means of Wilkinson's signed rank test[32 33] (keeping only one control, that which matches the case best).

Statistical tests have been conducted with a first order risk of 5%. A non-significant result is referred to as NS. In the case of significant results the degree of significance p is quoted.

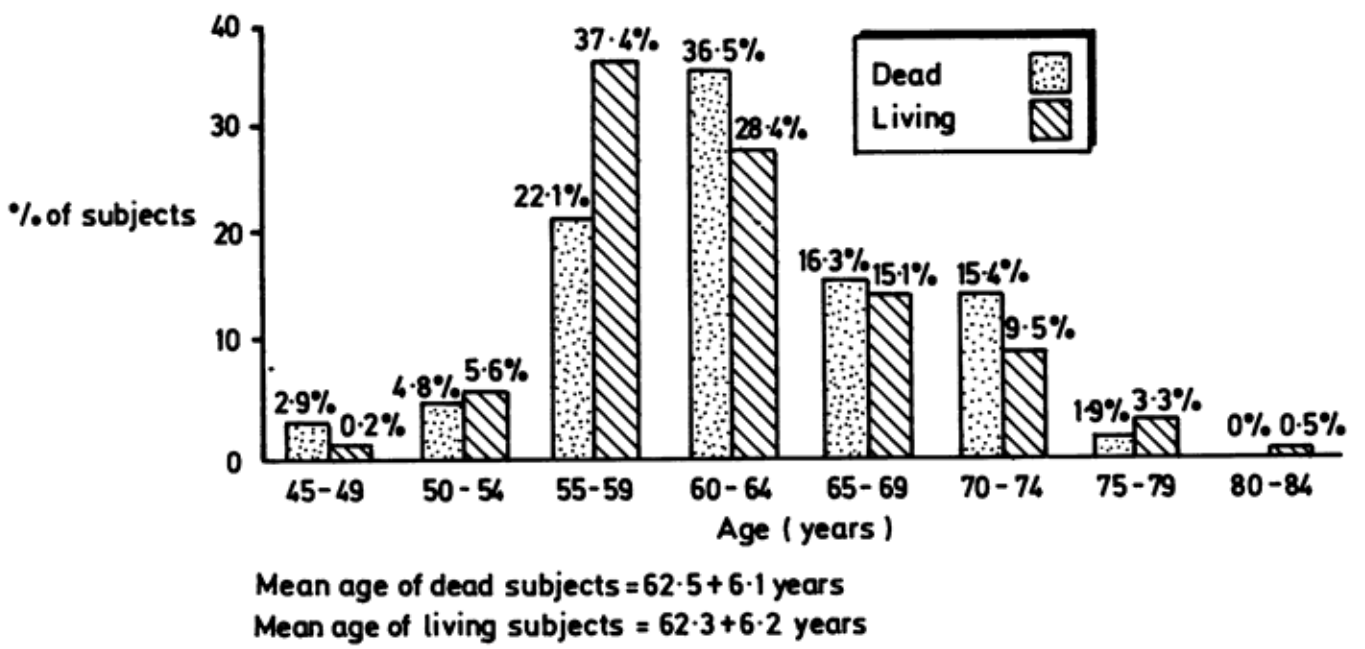
Results

The figure shows the histogram of the age of the subjects alive on 1 January 1983 and of the employees who died during the investigated period. In the cohort considered those aged 55–64 accounts for the largest part (59% of the dead subjects and 66% of the living). Both dead and living subjects have the same mean age (62 ± 6).

Table 2 shows the distribution of the main causes of death. Undefined causes of death, most of them referred to as unexpected deaths and unknown causes, account for 11% of the total, which is nearly the same rate as in the national statistics established by the INSERM.

Cancers account for 34% of deaths; their distribution by site is given in table 3. Lung cancers represent 16% of the causes of death and 49% of the cancers; 76% of the subjects who died from lung cancer were under 65.

In table 4 the cohort mortality is compared with



Age histogram of dead and living subjects on 1 January 1983.

Table 4 *Comparison of the cohort mortality with the French male mortality*

Main cause of death	*O*	*O/E*	*(1)*
Cancers:	35	1·15	NS
Lung	17	2·51	p < 1%
URAC	2	0·47	NS
Other	16	0·83	NS
Other causes	69	1·08	NS
All causes	104	1·10	NS

(1) Test of equality between O and E.
URAC: Upper respiratory and alimentary tract cancer.

that of the whole French male population. The overall mortality of the cohort (all causes together) is a little higher than expected, but not significantly so (SMR = 1·10).

Although the number of observed cancers is higher than expected, this excess is not significant (SMR = 1·15). Mortality due to lung cancer in our cohort is significantly higher than expected (SMR = 2·51). On the other hand, there is a less than average mortality (not statistically significant) for upper respiratory and alimentary tract cancer (SMR = 0·47). The other cancers are also underrepresented in our sample (SMR = 0·83).

COMPARISON OF MORTALITY BETWEEN THE TWO COKE OVEN PLANTS

Table 5 analyses separately the mortality of the operatives from each of the two plants by comparison with the mortality of the French population. The slight non-significant excess of mortality is almost the same in the two plants (SMR = 1·07 and SMR = 1·15). Lung cancers, however, account for 63% of cancers and 20% of deaths for plant A; 31% of cancers and 11% of deaths for plant B. The excess of lung cancer mortality is more pronounced for A (SMR = 3·05) than for B (SMR = 1·75). It is significant (p < 0·01) for A but not for B. This relative difference could be explained by the more noxious effects of the old plant A which was transformed in 1963. The other types of cancer are relatively more frequent for B (SMR = 1·13) than for A (SMR = 0·50) but the difference is not significant. It should nevertheless be noted that the analysis has been conducted on a small number of cases.

INFLUENCE OF EXPOSURE TO DUST, GAS, AND FUMES

Let us recall that this exposure concerns subjects working constantly on ovens, near ovens, and maintenance personnel with intermittent exposure on ovens. The degree of exposure is determined by the working duration at these workplaces. Table 6 gives the mortality of workers not exposed or exposed for less than five years compared with that of workers exposed for five years or more.

As above, the SMR of subgroups has been calculated with reference to the French male population. Only lung cancer mortality is significantly higher than

Table 5 *Mortality of workers from the coke oven plants*

	Plant A			*Plant B*			
Main cause of death	*O*	*SMR*	*(1)*	*O*	*SMR*	*(1)*	*(2)*
Cancers:	19	1·07	NS	16	1·27	NS	NS
Lung	12	3·05	p < 1%	5	1·75	NS	NS
URAC	1	0·41	NS	1	0·55	NS	NS
Other	6	0·52	NS	10	1·27	NS	NS
Other causes	41	1·07	NS	28	1·08	NS	NS
All causes	60	1·07	NS	44	1·15	NS	NS

(1)Test of equality between O and E.
(2) Homogeneity chi-square test of SMR corresponding to the coke plants.
URAC: Upper respiratory and alimentary tract cancer.

Table 6 *Mortality and occupational exposure to dust, gas, and fumes*

	Not exposed or exposed for <5 years			*Exposed for ≥5 years*			
Main cause of death	*O*	*SMR*	*(1)*	*O*	*SMR*	*(1)*	*(2)*
Cancers:	22	1·15	NS	13	1·15	NS	NS
Lung	10	2·35	p < 5%	7	2·78	p < 5%	NS
URAC	2	0·75	NS	0	0 (E = 1·57)	NS	NS
Other	10	0·82	NS	6	0·83		
Other causes	47	1·16	NS	22	0·92	NS	NS
All causes	69	1·16	NS	35	0·99	NS	NS

(1), (2), and URAC, see table 5.

expected in the two groups. The SMR of the group of men exposed for five years or more equals 2·78, which is a little higher than that of those non-exposed or exposed for less than five years (2·35). The homogeneity test of the corresponding SMR does not show a significant difference of mortality due to lung cancer between the two groups.

The statistical analysis has also been carried out on other criteria of exposure—namely, sole exposure on the ovens, exposure for which the carcinogenic risk appeared the highest in the studies of Lloyd and Redmond.[17] The results of the investigation, which were, with a smaller number of subjects, similar to the results related to exposure to dust, gas, and fumes are not shown here.

CASE-CONTROL ANALYSIS OF DEATHS FROM LUNG CANCER

The influence of tobacco as an extra-occupational risk has been investigated for all subjects who died. We managed to obtain details of the smoking habits of 77 of the 104 dead subjects (74%). Table 7 shows the distribution of causes of death among smokers and non-smokers. The proportion of deaths due to cancer is linked to smoking habits: 29% cancers for non-smokers, 42% cancers for smokers but this difference is not significant.

Smoking significantly increases the risk of lung cancer which is why we have conducted an analysis of pairmates as regards the influence of occupational exposure, matching on their smoking habits: the proportion of subjects exposed to dust, gas, and fumes is more important among those who died from lung cancers (47·1%) than among their pairmates (35·2%), but the difference is not statistically significant (table 8). In addition, the Wilcoxon test does not show any significant difference in occupational exposure between the cases and their pairmates.

Discussion

This study analysed the cancer mortality of the coke oven plants among retired workers in the Lorraine coalmining industry. Thus we have necessarily to deal with subjects older than 55, except for a few workers who retired early. As the ages characterised by a high proportion of deaths from lung cancers range between 45 and 74 and the deaths occurring earlier than 55 happened during the working period (out of 65 deaths observed, seven were from lung cancer), the exclusion of the latter (those dying before reaching retirement age) may lead us to underestimate the mortality due to lung cancers. The investigated cohort could have been made up of the total number of workers present in the coke plants at the beginning of the observation period, in 1963. This was not possible because the mining social security loses track of the dismissed workers and of those who resigned or were transferred to other plants. Sometimes, their departure is due to health reasons.

The percentage of unknown causes of death (11%) is considered satisfactory since it corresponds to national statistics.

Let us recall that the analysis of mortality is conducted with reference to the French male population. Since the mortality due to lung cancers is 1·3 times higher in Lorraine than in the whole country (1·6 times higher in the Moselle district which is a part of the region of Lorraine) for the years 1968, 1969, and 1970 it would be more appropriate to take a regional reference into account, but the statistics are not available for the years 1963–74.

Some studies on causes of death and occupation have shown a global mortality that is lower than average by comparison with the regional or national reference, a phenomenon known as the healthy worker effect.[8–35] In our study the number of deaths is slightly higher than expected. The mortality from cancers of all locations is not significantly higher than that of the French population. With regard to non-fatal cancers, no skin cancer has been observed.

Mortality due to lung cancer is 2·5 times higher than expected. Even if one takes into account the excess of mortality due to lung cancer in Moselle the excess of lung cancers among the cohort cannot be explained solely by the regional factor nor by the general excess of lung cancers among unskilled workers.[36] Besides, it cannot be accounted for by the confounding factors tobacco and alcohol because the deaths from upper respiratory and alimentary tract cancer are underrepresented in this investigation. The excess of lung cancers due to occupational exposure is plausible even though there is no correlation with duration of exposure to dust, gas, and fumes.

Table 7 *Cause of death and smoking habits*

Main cause of death	*Non-smokers*	*Smokers*	*Unknown*
Cancers:	7	22	6
Lung	1	14	2
Digestive system	4	5	2
Other	2	3	2
Other causes	17	31	21
All causes	24	53	27

Table 8 *Distribution of the lung cancers and the case-controls with regard to the exposure to dust, gas, and fumes (DGF)*

Exposure to DGF	*None*	*1–9 years*	*⩾ 10 years*
Lung cancers	9	4	4
Case-controls	22	3	9

Our results may be compared with those of other studies conducted on coke oven plants.[5 8 12 13 15 18 22 37] In 1971 Lloyd showed that in the coke oven plants of the Alleghany County, the mortality due to lung cancers among the men working on coke ovens was 2·5 times higher than that observed among other metallurgists.[12]

Lloyd[12] and Redmond *et al*[17] showed that the frequency of lung cancers was linked to the duration and relative level of exposure on the ovens. In Pennsylvania the men employed on the ovens for five years or more had a rate of mortality due to lung cancers 3·5 times higher than expected, whereas the rate of all the men working on ovens was 2·5 times higher than the normal rate. Redmond *et al* confirmed the existence of a relation between work on ovens and lung cancers[17]: the relative risk of lung cancers is 2·1 times higher than average for men working only near the ovens, 3·2 for men working above and near, and 6·9 for those working above the ovens.

Sakabe *et al* studied the mortality of 4655 retired employees from 36 metal works in Japan[22]: the mortality due to cancer of all sites and lung cancers was about equal to the expected frequency. They noticed, however, an excessive mortality due to lung cancers among the retired employees from four coke oven plants, eight cases of lung cancer for 3·4 expected; the difference was significant, though the investigated population was small.

Jacobsen and Hurley conducted an investigation on mortality in the British industries of coal carbonisation and tar distillation, studying a population of 4836 people from 1966 to 1975.[8] Deaths due to lung cancers were 29% higher than expected, the difference being statistically significant. Important variations were also noticed between the different plants investigated.

The variations of results among the different epidemiological surveys may be explained partly by methodological differences (definition of cohort, choice of reference population) and by the differences in technological processes and working methods on the batteries of ovens and also by differences in oven temperatures. These factors influence the type and concentration of toxic products generated by the ovens. They can also account for the relative high mortality due to lung cancers that was noticed in plant A compared with plant B (SMR = 3·05 *v* 1·75) in our study.

One may remark that dust, gas, and fumes do not constitute the only potential risks of lung cancers in those industries where there are also other harmful products such as asbestos, fumes, coal, or tar.

Conclusion

The mortality of the cohort of 534 retired workers from the Lorraine Collieries coke oven plants has been compared with that of the French male population. Among the 104 registered deaths, there was a significant excess of mortality due to lung cancers (17 cases observed; SMR = 2·51). Although there is no evidence of a relation between lung cancers and duration of exposure to PAH, the carcinogenic role of occupational nuisances cannot be excluded. Therefore, it is to be hoped that preventive arrangements will be taken to limit pollution at working places and to reduce the number of workers exposed.

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