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**Volume 34**  
**Polynuclear Aromatic Compounds,**  
**Part 3, Industrial Exposures in Aluminium Production,**  
**Coal Gasification, Coke Production,**  
**and Iron and Steel Founding**

**Summary of Data Reported and Evaluation**

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# ALUMINIUM PRODUCTION

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## 5. Summary of Data Reported and Evaluation

### 5.1 Exposures

Primary aluminium production plants are located in about 40 countries. The two main methods used for aluminium production are Söderberg and prebake, which encompass a number of processes and job categories. Substantial exposures to airborne polynuclear aromatic compounds have been measured in certain occupational settings in this industry. Exposures have been higher in potrooms of plants using the Söderberg process than in those using the prebake process; some workers may have been exposed to both processes. Exposures to fluorides and a variety of other contaminants also occur in potrooms.

### 5.2 Experimental data

Two incompletely characterized samples of airborne particulate polynuclear organic matter from an aluminium production plant were tested for carcinogenicity by skin application to mice, resulting in a high incidence and early appearance of papillomas and carcinomas of the skin.

Air samples from various locations in two aluminium production facilities were mutagenic to *Salmonella typhimurium*. No data on cell transformation were available.

### 5.3 Human data

Asthma, chronic pulmonary disease and skin lesions occur in potroom workers. Fluorosis has occurred in workers in the aluminium production industry.

The lung has been the most common site identified for excess cancer in populations of aluminium production workers. Overall, there was a borderline excess in relative risk, with some studies showing a doubling of risk and some showing no excess. No smoking history was given in any of these studies. In one study in which populations in the industry were compared on the basis of their exposures to pitch volatiles, there was a relationship between incidence of lung cancer and length of exposure, and a significant excess of cancer among workers who had worked for 21 years or more.

In three studies in the same aluminium-producing area, an increased risk of bladder cancer was associated with work in aluminium production in plants where primarily the Söderberg process was used. In one study in which smoking was controlled for, while there was a borderline excess in risk for non-smokers, the risk for smokers was markedly increased.

An excess of lymphosarcoma/reticulosarcoma was noted only in two cohort studies which covered partially the same population.

Statistically significant excess risks of pancreatic cancer and leukaemia were noted as isolated findings in two studies and in one study, respectively.

### 5.4 Evaluation

The available epidemiological studies provide *limited evidence* that certain exposures in the aluminium production industry are carcinogenic to humans, giving rise to cancer of the lung and bladder. A possible causative agent is pitch fume. There is *inadequate evidence* that occupational exposures in the aluminium

production industry result in haematolymphopoietic and pancreatic cancer.

There is *sufficient evidence* that samples of particulate polynuclear organic matter from one aluminium production plant were carcinogenic to experimental animals. However, because of the incomplete characterization of the samples tested, no evaluation of the carcinogenicity to experimental animals of complex mixtures that occur in the aluminium production industry could be made.

A number of individual polynuclear aromatic compounds for which there is *sufficient evidence* of carcinogenicity in experimental animals have been measured at high levels in air samples taken from certain areas in aluminium production plants.

Taken together, the available evidence indicates that certain exposures in the aluminium production industry are probably carcinogenic to humans.

For definition of the italicized terms, see [Preamble Evaluation](#).

**Subsequent evaluation:** [Suppl. 7 \(1987\)](#)

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# COAL GASIFICATION

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## 5. Summary of Data Reported and Evaluation

### 5.1 Exposures

Town gas and industrial gases derived from the destructive distillation of coal are produced in thousands of plants throughout the world. The processes are based on several gasifier designs. Substantial exposures to airborne polynuclear aromatic compounds, together with concomitant exposure to a variety of other contaminants, have been measured in retort houses. Polynuclear aromatic compounds were also measured in airborne samples and identified in surface samples from newer gasification plants.

### 5.2 Experimental data

Crude coal-tars from several older gas-works have been tested for carcinogenicity by skin application in mice and rabbits. All tars produced a high yield of skin papillomas and carcinomas. Various experiments have shown that the carcinogenicity of such tars cannot be attributed solely to their content of benzo[*a*]pyrene.

Two studies suggested that tar from horizontal retorts was more active in producing skin tumours in mice than tar from vertical retorts.

All process-stream and waste by-product samples tested which contained newer gasifier tars were mutagenic to *Salmonella typhimurium*. Samples of bottom ash from gasification systems did not show mutagenic activity. Several studies showed that mutagenic activity is found not only in fractions containing polynuclear aromatic compounds, but also in the more polar neutral, basic and total neutral fractions. The basic fraction of tar from one underground coal-gasification process was mutagenic and induced sister chromatid exchange in mammalian cells *in vitro*. No data on cell transformation were available.

### 5.3 Human data

Chronic bronchitis was reported to have occurred among employees in older gas-works.

Case reports of tumours of the skin (including the scrotum), bladder and respiratory tract in association with employment in industries involving the destructive distillation of coal suggested a link between that industry and human cancer. Despite their methodological shortcomings, the descriptive epidemiological studies based on death certificates corroborated these early suggestions.

A series of detailed analytical epidemiological studies of the British gas industry add further weight to the hypothesis that work in such coal gasification plants carries a risk of tumours of the lung, bladder and scrotum. Notwithstanding the limited details available on the work histories of the gas workers, there appeared to be a relationship between elevated relative risk of tumours and work in retort houses, particularly when the job entailed exposure to fume emanating from the retorts.

### 5.4 Evaluation

There is *sufficient evidence* from observations made in the first half of this century that occupational exposures to the products from the destructive distillation of coal give rise to skin cancer in humans.

The available epidemiological studies provide *sufficient evidence* that certain exposures in the retort houses of the older coal-gasification processes are carcinogenic to humans, giving rise to lung cancer. The likely

causative agent is coal-tar fume. There is *limited evidence* that such occupational exposures produce bladder cancer.

There is *sufficient evidence* that topical application of coal-tars from several older gas-works on the skin of experimental animals produced a high yield of skin cancers.

A number of individual polynuclear aromatic compounds for which there is *sufficient evidence* of carcinogenicity in experimental animals have been measured at high levels in air and tar samples taken from certain areas in coal-gasification plants.

The available evidence indicates that certain exposures in retort houses of older coal-gasification processes are carcinogenic to humans. No data on carcinogenicity in experimental animals or in humans from exposures during the newer processes were available to the Working Group.

For definition of the italicized terms, see [Preamble Evaluation](#).

**Subsequent evaluation:** [Suppl. 7 \(1987\)](#)

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# COKE PRODUCTION

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## 5. Summary of Data Reported and Evaluation

### 5.1 Exposures

The vast majority of coke is produced in by-product (slot) coke ovens. Substantial airborne exposures to polynuclear aromatic hydrocarbons have been measured in occupations in the production of coke. The highest exposures have been reported for workers on the topside of the coke-oven battery. The presence of other substances (including aromatic heteronuclear and substituted aromatic compounds) in the workplace air has been reported.

### 5.2 Experimental data

A sample from a coke-oven main was tested for carcinogenicity in mice by topical application and produced skin carcinomas. Samples obtained either from the topside or main of a coke oven showed initiating activity in a mouse-skin two-stage model. Samples of tar from coke ovens were also tested by inhalation in mice and rats, producing benign and malignant tumours of the lung; in one of these inhalation studies in mice, skin tumours were produced.

A sample from the topside of a coke oven was mutagenic to *Salmonella typhimurium* and in several mammalian cell systems (L5178Y mouse lymphoma, Chinese hamster ovary and BALB/c 3T3); it also induced DNA damage in Syrian hamster embryo cells and induced sister chromatid exchange in Chinese hamster ovary cells. The sample caused morphological transformation in BALB/c 3T3 cells and enhanced viral transformation of Syrian hamster embryo cells. A coke-oven sample taken from the gas-collector main was also mutagenic to *Salmonella typhimurium* and in mammalian cells (L5178Y mouse lymphoma) and induced sister chromatid exchange (in Chinese hamster ovary cells).

### 5.3 Human data

Chronic bronchitis occurs among coke-production workers, particularly in those who smoke.

Case reports of tumours of the skin (including the scrotum), bladder and respiratory tract in association with employment in industries involving the destructive distillation of coal suggested a link between that industry and human cancer. Despite their methodological shortcomings, the descriptive epidemiological studies based on death certificates corroborated these early suggestions.

The site at which excess cancer rates have been identified most commonly among workers in coke production is the lung. All but two of the relevant analytical epidemiological cohort studies provide evidence that work in coke production carries a significantly elevated risk of lung cancer. The two studies showing no excess suffered from serious methodological limitations. The risk for workers in the coke-oven area varied from three- to seven-fold, the highest risk being for men employed for five years or more and working fulltime on the topside of the coke oven. Few of the studies corrected for smoking.

Excess risk for kidney cancer has been associated with work in coke plants. In one study, a seven-fold increase in risk was seen for all workers employed for five years or more at coke ovens.

In single studies, excess risks were reported for cancers of the large intestine and pancreas.

### 5.4 Evaluation

There is *sufficient evidence* from observations made in the first half of this century that occupational exposures to the products of the destructive distillation of coal give rise to skin cancer in humans.

The available epidemiological studies provide *sufficient evidence* that certain exposures in the coke-production industry are carcinogenic to humans, giving rise to lung cancer. A possible causative agent is coal-tar fume. There is *limited evidence* that such occupational exposures produce cancer of the kidney, and *inadequate evidence* that they result in intestinal and pancreatic cancers.

There is *sufficient evidence* that samples of tars taken from coke ovens are carcinogenic to experimental animals, producing lung and skin tumours.

A number of individual polynuclear aromatic compounds for which there is *sufficient evidence* of carcinogenicity in experimental animals have been measured at high levels in air samples taken from certain areas in coke production plants.

The available evidence indicates that certain exposures in the coke production industry are carcinogenic to humans.

For definition of the italicized terms, see [Preamble Evaluation](#).

**Subsequent evaluation:** [Suppl. 7 \(1987\)](#)

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# IRON AND STEEL FOUNDING

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## 5. Summary of Data Reported and Evaluation

### 5.1 Exposures

The iron and steel foundry industry employs approximately two million workers. This industry is diverse in terms of materials and processes, resulting in occupational exposures to a variety of substances. Substantial exposures to silica and carbon monoxide continue to occur in many foundries. Occupational exposures to airborne polynuclear aromatic compounds have also been found, resulting mainly from the thermal decomposition of carbonaceous ingredients commonly added to foundry sand. In addition, some steel foundry workers (e.g., fettlers) are exposed to airborne chromium and nickel compounds. The introduction of new organic binder materials (beginning in the late 1950s) has resulted in new exposures of foundry workers to chemicals, including phenol, formaldehyde, isocyanates and various amines.

### 5.2 Experimental data

No data on the carcinogenicity to experimental animals of complex mixtures found in the iron and steel founding industry were available.

Numerous samples taken from the air in various locations in two iron and one steel foundries were mutagenic to *Salmonella typhimurium*. No data on cell transformation were available.

### 5.3 Human data

Chronic respiratory effects such as silicosis, other pneumoconioses and chronic bronchitis occur among foundry workers. Occupational asthma and dermatitis have also been described following the introduction of new chemical binders.

Data derived from reports of mortality statistics in the USA and the UK indicate excess mortality from lung cancer for 'foundry workers', but the definition of this occupational category included many occupational groups. Cancers of the digestive tract sometimes occurred in higher ratios than in the total population.

Analytical cohort epidemiological studies of foundry workers were carried out in a number of countries. Elevated risks of lung cancer (between about 1.5- and 2.5-fold), some of which were statistically significant, were observed in foundry workers when compared to the general population. In two study populations, comparison with other steel workers did not consistently reveal an elevated rate.

The proportion of lung cancers among all deaths was evaluated in some studies, and found to be about 1.5- to 1.8-fold higher than this proportion in the general population; however, there are difficulties associated with the interpretation of proportionate mortality ratios.

None of the cohort studies explicitly controlled for the potentially confounding smoking habits of foundry workers, although in some studies in which questionnaire data were used, the smoking habits of current workers were not significantly different from those of the general population. Other potential biases in these studies could have arisen from the imprecise classification of jobs.

An association between foundry work and lung cancer was observed in one case-control study.

In two studies, in which site-specific cancer deaths among iron and steel-foundry workers were compared with

the corresponding rates for the general population, significantly increased risks for cancer of the digestive system were observed: in one, the elevated risk was in the 'digestive system', in the other, it was in 'stomach cancer'.

Results from studies of a single cohort of steel-foundry workers in the USA showed a significantly elevated risk of 'cancer of the genito-urinary system' when compared with the entire steel-worker population under study, the risk being significantly elevated also for some specific sites (prostate and kidney).

#### **5.4 Evaluation**

The available epidemiological studies provide *limited evidence* that certain exposures in iron and steel founding are carcinogenic to humans, giving rise to lung cancer. There is *inadequate evidence* that such exposures result in cancers of the digestive system and genito-urinary system.

A number of individual compounds for which there is *sufficient evidence* of carcinogenicity have been measured at high levels in air samples taken from certain areas in iron and steel foundries.

Taken together, the available evidence indicates that occupational exposures occur in iron and steel founding which are probably carcinogenic to humans.

For definition of the italicized terms, see [Preamble Evaluation](#).

**Subsequent evaluation:** [Suppl. 7 \(1987\)](#)

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