# Dust and pneumoconiosis in the South African foundry industry

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**The objectives of this study were to estimate the extent of occupational health monitoring for dust and pneumoconiosis in the foundry industry and to assess dust levels and the prevalence of pneumoconiosis in a group of foundries. In only 13 (16%) of the 82 foundries that responded to a postal questionnaire were regular periodic full-sized chest radiographs done. Dust levels were measured every 3 years or more frequently in 20 foundries (24%). An uncontrolled dust hazard was evident in all 9 foundries surveyed between 1983 and 1992. The prevalence of silicosis ranged from 0% to 10,3% and increased with duration of service. The study provided convincing evidence of neglect of occupational health by the foundry industry.**

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Pneumoconiosis in foundry workers is a classic occupational disease well known in the industry. An important determinant of the risk of workers' developing this condition is the level of respirable quartz (the fine quartz dust capable of reaching the terminal parts of the lung). Respirable quartz levels below which pneumoconiosis will not occur have not been determined with certainty but the 'safe' 8-hour time-weighted average concentration of this hazard set by the American Conference of Governmental Industrial Hygienists (ACGIH) is widely accepted. The ACGIH safe concentrations are known as threshold limit values (TLVs) and the TLV for quartz is 0,1 mg/m$^3$.[1] Although the TLVs may not be common knowledge in the foundry industry it is widely known that dust control will prevent the disease and that radiological monitoring is required to identify affected workers. Consequently, dust levels in foundries, the prevalence of pneumoconiosis and the extent of provision of occupational health services to identify and control the condition will not only provide a measure of the pneumoconiosis problem but should also be an index of general occupational health activity. In short, if well-known hazards are uncontrolled it is unlikely that lesser-known ones will be. Dust measurement, dust control and pneumoconiosis prevalence and monitoring activities are thus fundamental in evaluating occupational health practice in dusty industries. With this in mind, we aimed to determine the extent of dust-related occupational health activity in the foundry industry and to review survey reports of dust measurements and pneumoconiosis prevalence in selected South African foundries.

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## Methods

### The foundry industry and dust-related occupational health activity

The 1989 Foundrylog (a directory of South African foundries compiled by the South African Institute of Foundrymen)[2] was chosen as the sampling frame. The geographical distribution of foundries in South Africa was determined from the addresses and postal codes listed in the Foundrylog. A postal questionnaire was sent to the management of all 185 foundries listed. It was mailed on three occasions at 2-monthly intervals to improve the response rate. The questionnaire aimed to collect information on the size of foundries, the moulding processes used, disease occurrence, incidence rates of pulmonary tuberculosis, occupational health services and attitudes towards regulations for health and hygiene monitoring.

### Dust control and pneumoconiosis prevalence in a group of foundries

To assess dust control and pneumoconiosis prevalence, workplace surveys conducted by the National Centre for Occupational Health (NCOH) from 1983 to 1992 were reviewed. The foundries had usually been surveyed at the request of workplace management and therefore did not constitute a random sample of national foundries. The foundries surveyed for dust were not necessarily surveyed for pneumoconiosis and vice versa.

### Dust levels

Respirable dust and respirable quartz measurements from 9 foundries were reviewed. The number of samples taken at each workplace varied from 7 to 121. The technique used for respirable dust measurement was personal gravimetric sampling in which dust samples with size-selecting cyclones were placed in the breathing zone of workers[3] selected by an experienced industrial hygienist. Workers thought to be representative of the important tasks in a particular section were selected — random sampling was therefore not used. The quartz content of respirable dust was determined at the NCOH by means of standard techniques for x-ray diffraction.[4]

### Pneumoconiosis prevalence

Pneumoconiosis prevalence was assessed by a review of radiographic surveys conducted at 10 foundries. The staff of the foundries varied in size, ranging from 49 to 1 249 workers. Usually all the workers were invited to participate in the survey but in 3 cases only long-service workers (> 10 years' service) participated. In the 9 NCOH surveys full-sized postero-anterior radiographs were taken on site by a trained radiographer with the NCOH mobile x-ray machine.

The radiographs were read by a single reader into the ILO Classification of Radiographs of Pneumoconioses.[5] Pneumoconiosis was diagnosed if there were small rounded opacities of 1/0 or more or if large opacities were present.

## Results

The Foundrylog[2] lists 185 foundries; unanswered questionnaires were returned from 24 stating that the enterprise in question had either closed down or was not a foundry. The maximum number of foundries potentially in operation was therefore 161.

Table I shows the response rates of these 161 foundries according to size of foundry. Fifty (31%) could not be categorised in respect of size due to missing data. Small concerns (< 50 workers) made up an important proportion (40,5%) of those that were size-categorised. Questionnaires were remailed to non-responding foundries twice giving each foundry a maximum of three opportunities to respond. The response to each mailing is shown in Table I. Although the final response rate was only 51% (82 foundries), the value of repeat mailing in improving response rates is clearly shown. The majority of the 161 foundries was in the PWV region (61%), with the Cape (14%), Natal (11%), Transvaal (10%) and OFS (3%) sharing the remainder.

The 82 respondents employed 10 826 foundry workers (excluding administrative staff). Since almost half the foundries did not respond, 21 652 (10 826 x 2) is a rough estimate of the number of workers employed in the industry.

Descriptive data obtained from the questionnaires are shown in Table II. Chemical binders may release dangerous agents such as isocyanates or formaldehyde into workplace air and their widespread use (by 70% of respondents) is cause for concern.

Only 13 foundries could recall ever diagnosing silicosis. Not surprisingly, the presence of an occupational health service (OHS) in the workplace increased silicosis diagnosis: 9 of the 23 foundries with an OHS reported silicosis while only 4 of the 57 without reported the disease (Yates corrected $\chi^2 = 10,17$; $P = 0,001$). Pulmonary tuberculosis diagnosis (49% of foundries) was similarly associated with OHS provision: 18 of the 23 OHS providers recalled tuberculosis cases compared with 22 of the 57 non-providers (Yates corrected $\chi^2 = 8,79$; $P = 0,003$). A total of 178 cases of tuberculosis were diagnosed in the 82 foundries in the 5 years preceding questionnaire completion. The reported annual incidence of tuberculosis was thus (178/5)/10 826 workers or $3,3 \times 10^{-3}$. The rates for foundries with and without OHSs were $3,8 \times 10^{-3}$ and $2,4 \times 10^{-3}$ respectively.

Twenty-three foundries (28%) answered yes to the question, 'Do you have a health service for your foundry?'

**Table I. Postal questionnaire response rates for 161 foundries according to foundry size**

| | | | Respondents | | | | |
|---|---|---|---|---|---|---|---|
| Size category* | No. | % | First response | Second response | Third response | Total | Non-respondents |
| Small | 45 | 28 | 13 | 15 | 2 | 30 | 15 |
| Medium | 42 | 26 | 9 | 15 | 5 | 29 | 13 |
| Large | 24 | 15 | 12 | 3 | 1 | 16 | 8 |
| Size unknown | 50 | 31 | 2 | 2 | 3 | 7 | 43 |
| Total (%) | | | 36 (22) | 35 (22) | 11 (7) | 82 (51) | 79 (49) |

* Small = < 50 workers, medium = 50 - 199 workers, large = > 200 workers.

**Table II. Occupational health information supplied by 82 foundries via questionnaire**

| | Response | | | | | |
|---|---|---|---|---|---|---|
| | Yes | | No | | No answer | |
| Question | No. | (%) | No. | (%) | No. | (%) |
| Chemical binders used in sand moulds? | 57 | (70) | 25 | (30) | 0 | |
| Silicosis ever diagnosed? | 13 | (16) | 68 | (83) | 1 | (1) |
| Pulmonary tuberculosis ever diagnosed? | 40 | (49) | 41 | (50) | 1 | (1) |
| OHS provided? | 23 | (28) | 57 | (70) | 2 | (2) |
| Provide worker education on hazards of dust? | 9 | (11) | 69 | (84) | 4 | (5) |
| Pre-employment CR taken? | 13 | (16) | 66 | (80) | 3 | (4) |
| Regular* periodic CRs taken? | 31 | (38) | 47 | (57) | 4 | (5) |
| Regular* periodic full-sized CRs? | 13 | (16) | 63 | (77) | 6 | (7) |
| Respiratory protective equipment provided? | 77 | (94) | 3 | (4) | 2 | (2) |
| Dust measurements ever done? | 46 | (56) | 34 | (42) | 2 | (2) |
| Dust measured regularly*? | 20 | (24) | 50 | (61) | 12 | (15) |
| Should regulations exist for monitoring workers? | 61 | (74) | 14 | (17) | 7 | (9) |
| Should regulations exist for monitoring dust? | 56 | (68) | 16 | (20) | 10 | (12) |

OHS = occupational health service which provides services beyond first aid; CR = chest radiograph, either miniature or full-sized.
* Regular = 3-yearly or more frequently.

OHS provision was significantly associated with increasing size of workplace (large — ≥ 200, medium — 50 - 199 and small — < 50; $\chi^2$ = 25,15; $P$ = 0,000). Twenty of the 23 OHSs were on the foundry premises and the most common staff complement was a full-time nurse and a part-time doctor (19/23 OHSs).

Only a small proportion of workplaces carried out basic occupational health tasks such as worker education (11%), regular periodic full-size chest radiography (13%) or regular dust level measurement (20%). Large foundries were most likely to provide these services ($P$ < 0,05 for $\chi^2$ test for each service separately). The provision of respiratory protective equipment was common (94%) despite its being a generally unsatisfactory method of reducing dust inhalation.

An encouraging finding was the generally positive response to the introduction of regulations for monitoring workers and dust levels. Not surprisingly workplaces which already provided services were more likely to support the introduction of regulations. For example, the current provision of regular periodic chest radiography was significantly associated with support for regulations to monitor workers (Yates corrected $\chi^2$ = 7,18; $P$ = 0,007). Of the 27 small foundries that answered the question on regulations for monitoring workers, 18 (66%) were in favour of regulation.

Table III shows respirable dust and respirable quartz measurements in all 9 foundries surveyed between 1983 and 1992. The time-weighted average TLV for quartz (0,1 mg/m$^3$)[1] was used as a standard for evaluating the quartz hazard. In some surveys quartz concentrations were presented as the percentage of quartz in respirable dust. In these cases a now defunct formula was used to calculate the TLV for dust:

$$10 \text{ mg/m}^3 \, / \, \% \text{ respirable quartz} + 2.$$

Where quartz determinations were not made (three surveys in 1986) it was assumed that the proportion of quartz in respirable dust was 8%; this set the TLV for respirable dust at 1 mg/m$^3$ (10 mg/m$^3$/[8+2]).

Table III provides clear evidence of an uncontrolled dust hazard in all the foundries surveyed. The TLV was exceeded in the majority of measurements in 7 of the foundries and also in almost all the foundry sections in which dust was measured. The extent of the dust hazard is clearly shown in the upper quartile figures for respirable quartz. In all cases these quartiles exceeded 0,3 mg/m$^3$; at least one-quarter of the quartz measurements were therefore three or more times higher than the TLV.

Table IV shows the radiological findings from 10 foundries surveyed between 1983 and 1992. The 1987 foundry was in the Western Cape, the remainder were in the PWV area. The percentage of workers with silicosis surveyed in each foundry ranged from 0% to 10,3%. It is important to note that many of the surveys included workers who had little chance of having the disease, e.g. those with short service or those employed in low-dust jobs. If only long-service, high-exposure workers were radiographed it is likely that the calculated prevalence of workers with silicosis would be higher in most of the foundries. This is confirmed by the generally higher prevalence in the workers with longer service.

**Table III. Respirable dust and respirable quartz levels in foundries in the PWV — 1983 - 1992**

| | Respirable dust measurements (mg/m$^3$) | | | | Quartz in respirable dust (mg/m$^3$)* | | | | Foundry sections† surveyed | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year of survey | No. | Median | Interquartile range (25 - 75%) | Exceeded TLV (%) | No. | Median | Interquartile range (25 - 75%) | Exceeded TLV (%) | No. | Quartz levels > TLV |
| 1983[6] | 121 | 1,9 | 0,9 - 4,9 | 79 | 23<br>46 | 0,15<br>6,8 | 0,07 - 0,38<br>1,7 - 16,7 | 96 | 7 | SP, CM, MO, SM, SB, FE, GE |
| 1984[7] | 110 | 1,8 | 1,0 - 3,3 | 81 | 97 | 0,21<br>9,4 | 0,13 - 0,31<br>6,7 - 18,9 | 85 | 8 | SP, CM, MO, SM, SB, FE, GE |
| 1986[8] | 52 | 3,1 | 1,8 - 7,4 | 92 | 5 | 13,4 | 6,9 - 16,3 | Data unavailable | 6 | SP, CM, MO, SM, SO, FE |
| 1986[9] | 32 | 1,4 | 0,7 - 3,1 | 47 | 9 | 4,4 | 2,1 - 10,0 | Data unavailable | 4 | CM, MO, SO, FE |
| 1986[10] | 7 | 2,5 | 0,8 - 2,9 | 71 | 0 | | | | 4 | SP, MO, SO, FE |
| 1986[11] | 15 | 1,2 | 1,0 - 1,8 | 87 | 0 | | | | 5 | SP, CM, MO, SO, FE |
| 1986‡[12] | 15 | 1,8 | 1,2 - 3,7 | 89 | 11 | 15,5 | 8,5 - 34,1 | 100 | 3 | MO, SO, FE |
| 1987[13] | 27 | 1,9 | 1,3 - 5,3 | 89 | 0 | | | | 6 | SP, MO, SM, SO, FE |
| 1992‡[14] | 25 | 3,0 | 1,6 - 6,5 | 68 | 15 | 0,2 | 0,1 - 0,43 | 73 | 8 | SP, CM, MO, SM, SO, SB, FE |
| 1992[15] | 29 | 1,6 | 0,6 - 3,9 | 44 | 27 | 0,05 | 0,04 - 0,4 | 44 | 7 | CM, MO, SO, FE |

TLV = threshold limit value — time-weighted average for quartz.
* Quartz levels given in mg/m$^3$ unless level followed by '%', in which case quartz in percentage of respirable dust.
† SP = sand plant, CM = core making, MO = moulding (including floor-moulding), SM = smelting (including furnace masonry), SO = shake-out, SB = shot-blasting, FE = fettling (including grinding, torch cutting and gouging), GE = general work (including cleaning and unskilled labour around the furnaces).
‡ Same foundry: surveyed in 1986 and 1992.

**Table IV. Radiological prevalences of silicosis in foundries, 1983 - 1992**

| Year of survey | Workers: Employed | Radiographed: No. | Radiographed: (%) | Silicosis in radiographed workers (%) | Silicosis by duration of service: Duration (yrs) | Silicosis by duration of service: % |
|---|---|---|---|---|---|---|
| 1983[6] | 1 249 | 1 121 | 90 | 6,7 | Data unavailable | Data unavailable |
| 1984*[7] | 574 | 513 | 89 | 5,6 | 0 - 10 | 2,3 |
| | | | | | > 10 - 20 | 7,1 |
| | | | | | > 20 | 23,9 |
| 1987†[16] | 116 | 116 | 100 | 10,3 | <15 | 3,5 |
| | | | | | >15 | 38 |
| 1988[17] | 56 | 56 | 100 | 0 | >10 | 0 |
| 1991‡[18] | 161 | 130 | 81 | 2,3 | ⩾10 | 2,3 |
| 1991‡[18] | 56 | 53 | 94 | 5,7 | ⩾10 | 5,7 |
| 1991[18] | 102 | 100 | 98 | 2,0 | >10 | 7,7 |
| 1992‡[18] | 49 | 49 | 100 | 4,0 | ⩾10 | 4,0 |
| 1992[19] | 385 | 364 | 95 | 2,7 | ⩾15 | 4,0 |

* Combined data from two Pretoria foundries.
† Data from W. Cape foundry surveyed by Myers *et al.*
‡ Only workers with 10 or more years' service participated; no. of workers employed = number ⩾ 10 years' service.

# Discussion

This study relied partly on information collected from a postal questionnaire to measure aspects of occupational health service activity in South African foundries. The response rate of 51%, although typical[20] is therefore disappointing as results may not be generalisable to the whole industry. It is unlikely that a better response rate would have painted a brighter picture of occupational health practice in this industry, however, as it is likely that foundries with poorly developed services would be more reluctant to complete a questionnaire than those with more comprehensive services.

The basic occupational health activities required to manage the well-known hazard of excessive dust were not undertaken in most foundries. The absence of specific regulations and the non-enforcement of others is one explanation for this poor performance by the industry. Whatever the reason, since services have not developed over time, relatively substantial investment of money and resources is required to bring occupational health practice to an acceptable standard. It is the perception of foundry management (expressed at a seminar of the South African Institute of Foundrymen, Johannesburg, 1992) that this investment will be damaging to the industry if it takes place in one step over a short period and that a staged introduction of monitoring programmes may be necessary, e.g. radiography of long-service and heavily exposed workers as the first stage, followed later by the introduction of pre-employment radiographs and then regular periodic radiographs of all workers.

Worker education deserves special mention. 'The right to know' about hazards and their control is a basic tenet of occupational health. In addition, employers have a legal obligation in this regard under the Machinery and Occupational Safety Act (Act No. 6 of 1983). Nevertheless, only 11% of workplaces provided an education programme on the health hazards of dust inhalation.

The reported pulmonary tuberculosis incidence of $3,3 \times 10^{-3}$/year is subject to many sources of bias (e.g. poor recall of cases, inappropriate diagnostic criteria) and should be interpreted cautiously. A postal questionnaire survey of tuberculosis rates in industry in the Western Cape found an overall incidence of $4,7 \times 10^{-3}$ and $7,7 \times 10^{-3}$ for the iron and steel industry.[21] Of interest is the increased reporting of pulmonary tuberculosis by foundries with an OHS. This may be due to better medical record-keeping by workplaces with an OHS but may be due to improved case-finding. The latter possibility deserves further investigation as factories may reject tuberculosis case-finding activity on the premise that cases will be diagnosed by general health services in any event, and thereby render OHS activity redundant.

The support for regulation of occupational health services probably reflects a desire among competitors for a 'level playing field' that will eliminate 'unfair' cost-containment through avoidance of OHS expenditure. Subsequent discussion with foundry management (at a seminar of the South African Institute of Foundrymen, Johannesburg, 1992) showed that the support for regulations was not without reservation. Seminar delegates were concerned that the cost of implementing occupational health regulations would lead to closure of financially marginal concerns, decrease investment in South African foundries in favour of investment in unregulated regions and allow informal small concerns to operate more cheaply by avoiding regulation. The merits of these fears have not been evaluated but they need to be addressed so that resistance to acceptable OH practices can be reduced.

All the dust measurement surveys took place in foundries in the PWV area and the appropriateness of generalising findings to the rest of South Africa is not known. The overall importance of the PWV bias is reduced since 61% of foundries were located in this region. Although foundry management usually requested the survey this may have been in response to pressure from workers or the factory inspectorate. Consequently, surveys may be biased towards dustier workplaces as it is possible that the most pressure would have been applied in foundries with the most obvious dust problems. A further consideration is that surveys do not always aim to measure the full range of dust levels in a workplace. The aim may be to locate the hazardous worksites, and dustier sites may therefore be preferentially selected. The dust levels presented in this study should be read with this in mind. What is clear from Table III is that most sections of all foundries surveyed had unacceptably high dust levels. These dust levels can be compared with 1 743 personal air samples collected between 1976 and 1981 from 205 foundries in the USA.[22] The median respirable dust level in the USA was 0,90 mg/m$^3$ with a median percentage quartz in this dust of 9%. Our data, collected a decade or more later, show a foundry median for respirable dust of 1,9 mg/m$^3$ which suggests that South African foundries had not yet attained USA standards of the 1970s.

Silicosis prevalences (Table IV) have the same generalisability constraints as do the dust measurements. The wide range of disease prevalence (0 - 38% for longer service workers) may be explained in part by factors inherent in the production processes (e.g. extent to which sand moulds are used) or by employment policies such as dismissal of workers with silicosis. Of importance is that most of the workers with pneumoconiosis identified were undiagnosed prior to the surveys and working in high-dust sections despite having pneumoconiosis.

In conclusion, this study provides convincing evidence of neglect of occupational health by the foundry industry. Inadequate dust control and monitoring of exposed workers are the norm and it is reasonable to conclude that conditions and hazards less well known than pneumoconiosis and dust receive even less attention.

The industrial hygiene section of the NCOH conducted the dust measurement surveys and we were fortunate to have access to these important data. Kate Hlazane and Enrico Muller helped with the foundry questionnaire and data management. We would also like to thank Gill Nelson and R. E. G. Rendall for commenting on an earlier version of the paper.

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HISTORY OF MEDICINE

# Constipation, purgatives or the knife?

## A 19th-century dilemma

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Research into the history of laxative abuse requires analysis of prevailing attitudes towards, and definitions of, constipation, both 'lay' and 'professional'. A review of the medical literature of the last decade of the 19th century reveals concern with the causes and treatment of constipation, and while there are cautions against the indiscriminate use of laxatives, no studies were found on laxative abuse as such.

Constipation was found in about 60% of patients, was more common in women,[1] and affected young and old, 'peasant' and 'potentate', although it was 'somewhat aristocratic in its tendencies, showing a special fondness for the highborn and the wealthy, not to be wondered at when their diet and inactive habits are remembered'. Furthermore, their luxurious water-closets distracted them from 'exclusive attention to the act', and 'calls to stool' were possibly neglected or postponed by 'false modesty'.[2] Was this 'aristocratic tendency' noted merely because the 'highborn' could afford and therefore more often consulted the doctor?

There was general agreement by the profession that constipation was caused by diminished muscularity and mucosal secretions of the bowel and defective innervation, and most authors recognised the primary roles played by diet and exercise. Constipation was defined as an 'abnormal condition of the great colon and entire intestinal tract manifested by unusual retention of excrementitious material both as to quantity and time of evacuation',[1] or 'modification of the alimentary canal resulting in the retention of faecal matter'.[2]

However, there was not consensus about regularity, and while some doctors accepted a wide range of normal function, claiming that 'remarkable differences in individual habit may not be incompatible with ordinary health',[2] there were hardliners who insisted on 'an easy regular movement every morning, so soon as they have breakfasted', making those persons 'meek, affable, gracious, kind, and "no" from their mouth comes with more grace than "yes" from the mouth of one who is constipated'.[1]

Dr E. S. Pettyjohn[1] further alarms the public by declaring that 'since the fecal matter is toxic, how can the guilty (those who do not believe in defecation), or even the innocent escape destruction?' One wonders what effect those moral judgements of one's bowel habits must have had on the constipated — committing them shamefacedly to lifelong surreptitious addiction to Merrie & Bright laxative sweets (containing phenolphthalein), Allen & Hanbury's

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