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Epidemiologic studies of occupational cancer as related to complex mixtures of trace elements in the art glass industry

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WINGREN G, AXELSON O. Epidemiologic studies of occupational cancer as related to complex mixtures of trace elements in the art glass industry. *Scand J Work Environ Health* 1993;19 suppl 1:95—100. In the art glass industry workers run increased risks of dying from several types of cancer, cardiovascular diseases, and cerebrovascular diseases. This paper considers the diseases of glass workers in relation to exposure to particular elements, a high degree of correlation being found for some of them. Case-referent evaluations showed an association between stomach cancer and exposure to a mixture of elements, namely, arsenic, copper, nickel, and manganese, and to some extent also to lead and chromium. For colon cancer, a clearly increasing trend in risk was seen with increasing use of antimony, and to some extent also with increasing use of lead, the two elements being strongly correlated. For lung cancer no obvious correlation with any metal could be found. In addition, the risk for death from cardiovascular disease was fairly evenly distributed, although slightly more related to increasing consumption of the strongly correlated metals nickel and copper.

Key terms: antimony, cardiovascular, metals, mixed exposure, selenium.

Mixed exposures to metals and other trace elements occur in many industrial activities such as welding, foundry work, and metal ore processing. Cancer risks have been associated with several of these complex exposures in studies from various countries. For many of these processes, however, it is still unclear whether particular compounds are entirely or at least mainly responsible for cancer development or if the combined exposure to several metals and other agents constitutes the risk. Usually, however, a particular trace element or some other agent is singled out as the factor under consideration in any particular study, but other concomitant exposures might be of some importance for the risks seen, either because of interaction in the biological sense or because of confounding. This possibility might apply both to studies of workplace exposures and to health hazards in the general environment. Decreased risks might also result from protective interaction or negative confounding. The multistage nature of the carcinogenic process certainly also favors the idea that the combination of and interaction between several agents (eg, in the work environment) might enhance or inhibit the development of cancer, as found in certain experimental situations (1).

An industry with a fairly complex exposure pattern has come into focus recently, namely, the glass industry. The work environment in the art glass industry is very complex, even if the methods of art glass production may seem relatively simple and uniform since they depend more on manual skill than on machinery. However, precisely because of the predominantly manual nature of the process, workers come into close contact with a variety of potentially hazardous agents.

This paper focuses on the cancer risks that have not yet been extensively reviewed and discussed for art glass workers in the literature. The problems encountered in studies of complex environments are well illustrated by some original data, presented by us, on cancer in relation to mixed exposures to various metallic compounds.

Soda glass, generally used for the production of tableware, is made from quartz, soda, and chalk. In crystal glass production, the main components are quartz, potash, and lead oxide. Saltpeter and arsenic, in the form of arsenic trioxide, or more recently antimony, as antimony trioxide, are used as fining agents (ie, they are added to ensure mixing of the molten glass and to remove air bubbles during the melting process). Oxides of several metals (eg, copper, cobalt, chromium, iron, nickel, and manganese) as well as cadmium sulfide, but also metallic copper, gold, and selenium, can be used for various purposes. Borax can be found in paints used on glass.

Large amounts of hydrofluoric acid and sulfuric acid are used in the polishing process, and, in the past, and especially from the early 1950s to the mid 1970s, various asbestos products were used in the furnaces and for handling hot glass. The ambient air in glassworks not only contains dust, but also sulfur

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oxides and nitrogen oxides emanating from the molten glass or from the combustion of oil. Many of the metals from the molten glass are liable to react with sulfur dioxide, forming sulfates (2). Glass workers are also highly exposed to the combustion products of oil, wooden molds, and other organic materials, such as the wet newspapers, printing ink included, used to form hot glass bulbs. Furthermore, the effect of heat stress from the furnaces has not yet been evaluated in connection with exposure to chemical agents.

Several epidemiologic studies from Sweden and other countries have shown that art glassworkers run increased risks of dying from cancer of various types and from cardiovascular and cerebrovascular diseases. The results are summarized in tables 1 and 2. Since several more or less well-established carcinogenic elements are present in art glass production, the cancer risks observed among glass workers in various countries are probably due to occupational exposures. The observed adverse effects on the cardio- and cerebrovascular systems of Swedish glass workers may also be related to such exposures. However, the specific agents or combinations of agents responsible for the various health effects have not yet been clearly pinpointed. We have therefore made an attempt to reconsider our own data, with the aim of relating the cancer risks somewhat more specifical-

Table 1. Glass workers and health effects — a summary of case-referent and cohort studies. (OR = odds ratio, SMR = standardized mortality ratio, SIR = standardized incidence ratio)

Study	Study design	Health effect	Risk estimate
Milne et al, 1983 (3)	Case-referent, mortality	Lung cancer	OR 2.2[a]
Wingren & Axelson, 1985 (18)	Case-referent, mortality	Stomach cancer	OR 2.0[a]
		Lung cancer	OR 2.0[a]
		Cardiovascular diseases	OR 1.4[a]
Wingren & Axelson, 1987 (4)	Case-referent mortality	Stomach cancer	OR 1.5[a]
		Colon cancer	OR 1.6[a]
		Lung cancer	OR 1.7[a]
		Cardiovascular disease	OR 1.2[a]
Cordioli et al, 1987 (5)	Cohort, mortality	Larynx cancer	SMR 4.5[a]
		Lung cancer	SMR 2.1[a]
Levin et al, 1988 (6)	Case-referent, incidence	Lung cancer	OR 5.1[a]
Mallin et al, 1989 (7)	Case-referent, mortality	Brain tumors	OR 3.0[a]
Sankila et al, 1990 (8)	Cohort, incidence	Lung cancer	SIR 1.3[a]
		Skin cancer	SIR 1.4
		Colon cancer	SIR 0.3
Wingren & Englander, 1990 (9)	Cohort, mortality	Pharyngeal cancer	SMR 9.9[a]
		Colon cancer	SMR 2.5
		Lung cancer	SMR 1.4
		Prostate cancer	SMR 1.3
		Ischemic heart disease	SMR 1.2
		Cerebrovascular diseases	SMR 1.5
González et al, 1991 (10)	Case-referent, incidence	Stomach cancer	OR 2.2
Wingren & Axelson, 1991 (11)	Case-referent mortality	Brain tumors	OR 1.3[a]

[a] Indicates significantly increased risk on the basis of the significance levels used in the different studies.

Table 2. Glass workers and health effects — a summary of register-based studies. (RR = relative risk, SIR = standardized incidence ratio, PCIR = proportional cancer incidence ratio)

Study	Study design	Health effect	Risk estimate
Englund et al 1982 (12)	Register-based, incidence	Brain tumors	RR 2.4
Lynge et al 1986 (13)	Register-based, incidence	Lung cancer	SIR 1.8[a]
McLaughlin et al, 1987 (14)	Register-based, incidence	Intracranial gliomas	SIR 1.6[a]
McLaughlin et al 1987 (15)	Register-based incidence	Meningiomas	SIR 5.2[a]
Malker et al 1990 (16)	Register-based, incidence	Nasopharyngeal cncer	SIR 6.2[a]
Hall & Rosenman, 1991 (17)	Register-based, incidence	Cancer of the trachea, bronchus, lung and pleura	PCIR 1.3[a]
		Mesothelioma	PCIR 14.7[a]

[a] Indicates significantly increased risk on the basis of the significance levels used in the different studies.

ly to the different exposure patterns occurring in glass production and, hence, to the specific combinations of elements involved.

Materials and methods

As reported in greater detail elsewhere (18), we have had access to data on the deceased population of 11 parishes covering the glass-producing area in southeast Sweden for the years 1950—1982. The material included men 45 years of age or older at the time of death. Altogether, 5499 subjects were enrolled, of whom 888 were glass workers. For the definition of cases, the causes of death were classified according to the eighth revision of the International Classification of Disease (ICD—8). Referents were men recorded in the register as having died from causes other than cancer or cardiovascular diseases.

Since it would hardly be possible to obtain individual data on specific exposures to metals and other agents over time for a group with such a varying and complex exposure as glass work, data on the consumption of chemicals linked with any particular type of production were obtained by means of questionnaires submitted to 13 glassworks currently in operation. Information was requested on the amounts of 10 different metals used annually at the glassworks both in the 1960s and currently. These metals were antimony, arsenic, cadmium, chromium, copper, lead, manganese, nickel, selenium, and zinc. Answers to the questionnaire were received from seven of the glassworks.

The number of subjects from the parishes in which the seven responding glassworks were located was reduced to 3523 men 45 years of age or older.

The information obtained on the consumption of the different metals in the 1960s was used for a correlation study and for cross-tabulation of cancer and cardiovascular death risks by the amount of metal consumed. For each of the metals studied, the glassworks were divided into three categories as follows: (i) glassworks consuming no amount of the metal, (ii) glassworks consuming small amounts (expressed as kilograms of metal per year and number of employees), and (iii) glassworks consuming large amounts (expressed in the same way). Glassworkers registered as deceased in a parish containing one of the seven glassworks were regarded as having been exposed according to the three categories defined, while the other men in the area were regarded as unexposed (ie, used as the reference). It should be noted, however, that there are differences of orders of magnitude between the amounts of the various metal compounds used, and therefore the exposure assessment should be regarded as essentially qualitative in character.

To evaluate the correlation between exposure to different metals, including the aspect of potential confounding, we considered the situation for the referents in this respect. Case-referent evaluations with stratification for age were then made with regard to the consumption of the 10 metals under consideration and the excess deaths for glass workers previously found, namely, from stomach, colon and lung cancer, as well as from cardiovascular diseases. Odds ratios (OR) and 90% confidence intervals (90% CI) were calculated as described by Mantel & Haenszel (19) and Miettinen (20). Three age strata were used, namely, 45—64, 65—74 and ≥75 years. The evaluations of exposure pattern were based on Pearson's correlation coefficient (r).

Not surprisingly, a high degree of correlation was found between the amounts consumed of many of the metals (ie, the potential exposure pattern was complex). This situation was inevitable because of the mixtures used in the production of particular items. Lead and arsenic are used in the production of most kinds of art glass, and therefore the amounts consumed are more or less strongly correlated with those of all the other compounds, though less so for lead versus cadmium, selenium, and zinc. Furthermore, the production of different types of colored glass implies a fairly strong correlation with the use of copper, nickel, chromium, and manganese compounds. A ruby-red glass is made by adding a combination of selenium and cadmium to the batch, and this practice is reflected by the strong correlation between the amounts of these two metals (table 3).

Table 3. Correlations of the exposure pattern among the referents for the consumption of various metals, mainly as oxides, in the seven glassworks studied.[a]

	Arsenic	Cadmium	Chromium	Copper	Lead	Manganese	Nickel	Antimony	Selenium	Zinc
Arsenic	1.0	0.62	0.20	0.80	0.52	0.33	0.46	0.25	0.38	0.66
Cadmium		1.0	−0.05	0.45	0.10	−0.05	−0.00	0.02	0.85	0.85
Chromium			1.0	0.56	0.46	0.88	0.56	−0.02	−0.02	0.04
Copper				1.0	0.53	0.50	0.81	−0.05	0.27	0.51
Lead					1.0	0.31	0.60	0.76	0.10	0.08
Manganese						1.0	0.38	−0.03	0.01	−0.04
Nickel							1.0	−0.03	0.04	−0.02
Antimony								1.0	0.05	−0.02
Selenium									1.0	0.45
Zinc										1.0

[a] Based on Pearson's correlation coefficient, r.

The case-referent evaluations showed a dose-related association among glassworkers between stomach cancer and exposure to, particularly, arsenic, copper, nickel, manganese, and to some extent lead and chromium as compared with the population not employed in glassworks (table 4). Formally, a decrease in stomach cancer risk was associated with increased exposure to the other main group of elements, namely, antimony, cadmium, selenium, and zinc; lack of exposure in this group on the other hand implies exposure to the first-mentioned group of elements, associated with an increased risk.

The correlation between exposure to manganese and chromium was especially strong (r = 0.88), but the dose-response relationship between these elements and stomach cancer was less clear than for copper and nickel, which, in turn, were also strongly correlated with one another (r = 0.81); both are also closely correlated with arsenic. However, arsenic, like lead, correlates fairly strongly with most of the other metals.

For colon cancer, a clearly increasing trend in risk was seen with increasing use of antimony, and to some extent also with increasing use of lead; decreasing trends were therefore seen for the metals whose consumption was poorly correlated with that of antimony. Lead consumption was correlated fairly strongly with that of antimony (table 5), a finding suggesting the possibility of confounding by antimony with regard to the effect of lead.

For lung cancer no obvious trend for any metal could be found, and none or very few lung cancer cases appeared in the highly exposed categories; the highest odds ratios were seen for low lead exposure and formally also for the absence of exposure to nickel. The risk of death from cardiovascular diseases was fairly evenly distributed between the different metal consuming groups, although slightly elevated risks were found for increasing consumption of the strongly correlated metals nickel and copper (r = 0.81), the odds ratios for both elements being 1.2 (90% CI 1.0—1.5) and 1.4 (90% CI 1.1—1.7) in the low- and high-exposure categories, respectively.

Table 4. Mantel-Haenszel odds ratios (OR) and 90% confidence intervals (90% CI) for stomach cancer for male glass workers and the consumption of metals. The reference is the local population not employed in glassworks. Pearson's correlation coefficient (r) is given for the correlation with the preceding metal and versus arsenic. The elements have been placed in order according to the highest odds ratio for high consumption.

Metal and r	r versus arsenic	Reference OR	Level of consumption					
			None		Low		High	
			OR	95% CI	OR	95% CI	OR	95% CI
Arsenic	1.0	1.0	·	·	1.0	0.6—1.7	2.2	1.5—3.3
Copper, 0.80	0.80	1.0	0.8	0.3—2.0	1.6	1.1—2.5	2.1	1.2—3.6
Nickel, 0.81	0.46	1.0	1.2	0.3—4.0	1.4	0.9—2.2	1.9	1.2—2.9
Manganese, 0.38	0.33	1.0	0.8	0.4—1.6	2.7	1.7—4.3	1.6	1.0—2.9
Lead, 0.31	0.52	1.0	·	·	1.7	1.0—2.8	1.5	1.0—2.3
Chromium, 0.46	0.20	1.0	1.2	0.7—2.1	2.2	1.4—3.5	1.4	0.7—2.7
Antimony, −0.02	0.25	1.0	2.0	1.3—3.1	1.6	0.9—2.6	0.8	0.3—2.0
Cadmium, 0.02	0.62	1.0	1.5	1.0—2.3	2.3	1.3—4.0	0.7	0.2—2.2
Selenium, 0.85	0.38	1.0	1.9	1.3—2.7	1.4	0.7—2.7	0.7	0.2—2.2
Zinc, 0.45	0.66	1.0	1.9	1.3—2.7	1.4	0.7—2.7	0.7	0.2—2.2

Table 5. Mantel-Haenszel odds ratios (OR) and 90% confidence intervals (90% CI) for colon cancer for male glass workers and the consumption of metals. The reference is the local population not employed in glassworks. Pearson's correlation coefficient (r) is given for the correlation with the preceding metal and versus antimony. The elements have been placed in order according to the highest odds ratio for high consumption.

Metal and r	r versus antimony	Reference OR	Level of consumption					
			None		Low		High	
			OR	95% CI	OR	95% CI	OR	95% CI
Antimony	1.0	1.0	1.4	0.6—3.3	1.8	0.8—13.8	5.0	2.6—9.6
Lead, 0.76	0.76	1.0	·	·	1.9	0.9—4.2	2.5	1.4—4.4
Manganese, 0.31	−0.03	1.0	3.4	1.8—6.5	1.6	0.6—4.3	1.8	0.8—3.8
Arsenic, 0.33	0.25	1.0	·	·	2.8	1.5—5.0	1.7	0.8—3.6
Chromium, 0.20	−0.02	1.0	3.4	1.9—6.1	1.3	0.5—3.5	1.7	0.6—4.4
Nickel, 0.56	−0.03	1.0	1.8	0.3—10	3.2	1.8—5.6	1.3	0.6—3.1
Copper, 0.81	−0.05	1.0	5.0	2.6—9.6	1.8	1.0—3.6	1.1	0.3—3.7
Cadmium, 0.45	0.02	1.0	2.5	1.4—4.4	2.4	1.0—5.7	1.0	0.2—5.6
Selenium, 0.85	0.05	1.0	2.8	1.7—4.9	1.7	0.6—4.4	1.0	0.2—5.6
Zinc, 0.45	−0.02	1.0	2.8	1.7—4.9	1.7	0.6—4.4	1.0	0.2—5.6

Discussion

Several studies indicate an increased cancer risk for glass workers, but there are some differences with regard to which cancers predominate. In light of our data it is possible that the somewhat inconsistent risk patterns found in these studies might be the result, at least in part, of differences in organ specificity, along with differences in exposure, depending on the particular kind of glass produced.

The analysis of our data reflects the difficulty in identifying the effect of individual components of a complex occupational exposure, especially when the process involves either more or less concomitant exposure to a number of agents, such as the various elements discussed in this paper, or separate exposures to individual agents. Hence neither traditional stratification nor regression analysis is capable of properly separating the effects, and the situation is made even worse by inaccuracy in the assessment of the exposures. (See reference 21.) However, a more general question also remains to be answered, namely, whether the specific agents are individually responsible for the risks seen or whether they exert their effect only in combination.

The same difficulty of separating the effects of specific factors in a multiple-exposure environment is also encountered in studies of many other occupations (eg, welders, foundry workers and smelters). The production process often inevitably implies a fairly strong correlation, whether positive or negative, with several factors, many of which may be associated with carcinogenic or other harmful effects. It may then be doubtful whether any attempt should be made to single out and study specific agents, since the complex chemical environment in itself might constitute the hazard as a result of interactions between otherwise less harmful substances. A work environment in which processes are carried out at high temperatures may also be hazardous because reactions between the various compounds may be caused or modified.

Our findings cannot be directly compared with any similar results from other studies of glassworkers since there are none in which an attempt was made to identify the effects of particular agents either alone or in combination. Moreover, our results are certainly open to question because the assessment of exposure is based on the consumption of metals in the 1960s only. They are nevertheless suggestive in some respects regarding the cancer risks associated with certain metals and their compounds. The fact that all of the glassworkers registered in a particular parish were assigned the metal consumption value for the glassworks located in that parish may reduce the accuracy of the exposure assessment, although we were told that the work force is very stable and that only a few workers come from outside the parish. In addition, some of the glassworkers who died early in the study period might have been employed in glassworks no longer in operation and therefore not contributing exposure information. This possibility could have affected the grouping of glass workers into the different exposure categories to some extent, but it is impossible to predict in what way such misclassification is likely to affect the risk estimates obtained.

The glassblowers were not separated from other types of glassworkers in this context both because of their small numbers for some exposure categories and because individuals with glassblowing experience may be given other job titles, especially in the relatively large group of unspecified glass workers. (See reference 18.)

Some measurements of air concentrations of arsenic, lead, manganese, and nickel were undertaken in connection with our epidemiologic studies, but only lead was found in any appreciable amounts, with a mean of 61 $\mu g \cdot m^{-3}$ (0.29 $\mu mol \cdot m^{-3}$) in the foundry of a heavy crystal glassworks (22). Oven inlay work resulted in up to 72 $\mu g \cdot m^{-3}$ (0.35 $\mu mol \cdot m^{-3}$) of lead in the air in both crystal and semicrystal glassworks.

The arsenic levels were less than 6 $\mu g \cdot m^{-3}$ (0.08 $\mu mol \cdot m^{-3}$) and nickel and manganese were not detectable, ie, less than 1 $\mu g \cdot m^{-3}$ (0.02 $\mu mol \cdot m^{-3}$). Higher levels may have occurred in the past, however, especially in the dusty process of batch mixing, which is currently carried out only in a special factory serving all the Swedish glassworks.

It should be noted that, in a German study, concentrations of antimony in the air were high in the batch chambers and batch mixers were found to have the highest urine concentrations of both antimony and lead (23). Another German report indicated that the blood lead levels of workers in the ceramic and glass industry were highest among batch mixers, smelters, workers charging furnaces, and glassmakers (24). In four German glass foundries, the air concentrations of nickel exceeded the recommended standard, and the urinary concentrations of this metal were higher for glassworkers than for an unexposed reference group (25).

We also measured arsenic, lead, manganese, and nickel in the slag from inside both ends of the blowpipes, and the results suggested some upward transportation of metals, resulting in oral exposure (22). An oral route of exposure is also clearly indicated by the fact that glassblowers experience a metallic taste and that their teeth tend to become discolored.

In view of both the results of the hygienic measurements and the epidemiologic findings, it is suggested that the increased cancer risks seen among glassworkers, especially gastrointestinal cancers among glassblowers, may be due to the ingestion, rather than the inhalation, of the agents responsible. The weak relationship between lung cancer and any of the specific agents considered, as well as the low air concentrations of the metals measured, except lead, indirectly support this conclusion and suggest that the widespread use of asbestos and possibly also exposure to combustion products might be responsible for this type of cancer. It should also be emphasized that the glassblowers were not particularly at risk for lung cancer; this finding also makes it less likely that their other cancer risks are the consequence of exposure via inhalation, even though many of the types of cancer under consideration have also appeared among insulation workers exposed to asbestos (26).

Since the risk of colon cancer was strongly associated with the use of antimony, and also lead, a causal relationship may exist, first and foremost, with antimony, but there is little direct support from the literature for this view. Similarly, there seem to be no comparable findings for stomach cancer and exposure to arsenic, nickel, or copper. An excess of stomach cancer has been seen in some groups of workers exposed to chromium, but there has not been any consistent pattern (27). The same applies to arsenic exposure (28) and to foundry work (29). The possible preventive role of selenium, as indicated to some extent by our data, is well recognized even if not generally accepted.

It would certainly be of great interest if future studies of glassworkers could be designed so as to focus more specifically on the effects of particular exposures, either to single agents or to certain complex combinations. Our findings then might be either confirmed or refuted, and such studies might suggest which particular combinations of trace elements would be worth testing for carcinogenicity in animal models.

References

1. Schmähl D. Combination effects in chemical carcinogenesis. Weinheim: VCH, 1988.
2. Statens Naturvårdsverk. Glasbrukens miljöproblem [Environmental problems in glassworks]. Stockholm: Statens Naturvårdsverk, 1978. (SNV PM 1023.)
3. Milne R, Sandler DP, Everson RB, Brown SM. Lung cancer and occupation in Alameda county: a death certificate case-control study. Am J Ind Med 1983;4:565—75.
4. Wingren G, Axelson O. Mortality in the Swedish glassworks industry. Scand J Work Environ Health 1987;13:412—6.
5. Cordioli G, Cuoghi L, Solari L, Berrino F, Crosignani P, Riboli E. Mortalitá per tumore in una coorte di lavoratori della industria de vetro. Epidemiol prevenzione 1987;30:16—8.
6. Levin LI, Zheng W, Blot WJ, Gao Y-T, Fraumeni Jr JF. Occupation and lung cancer in Shanghai: a case-control study. Br J Ind Med 1988;45:450—8.
7. Mallin K, Rubin M, Joo E. Occupational cancer mortality in Illinois white and black males, 1979—1984, for seven cancer sites. Am J Ind Med 1989;15:699—717.
8. Sankila R, Karjalainen S, Pukkala E, Oksanen H, Hakulinen T, Teppo L, et al. Cancer risk among glass factory workers: an excess of lung cancer? Br J Ind Med 1990;47:815—8.
9. Wingren G, Englander V. Mortality and cancer morbidity in a cohort of Swedish glassworkers. Int Arch Occup Environ Health 1990;62:253—7.
10. González CA, Sanz M, Marcos G, Pita S, Brullet E, Vida F, et al. Occupation and gastric cancer in Spain. Scand J Work Environ Health 1991;17:240—7.
11. Wingren G, Axelson O. Cluster of brain cancers spuriously suggesting occupational risk among glassworkers. Scand J Work Environ Health 1992;18:85—9.
12. Englund A, Ekman G, Zabrielski L. Occupational categories among brain tumor cases recorded in the cancer registry in Sweden. Ann NY Acad Sci 1982;381:188—96.
13. Lynge L, Kurppa K, Kristofersen L, Malker H, Sauli H. Silica dust and lung cancer: results from the Nordic occupational mortality and cancer incidence registers. JNCI 1986;77:883—9.
14. McLaughlin JK, Malker HSR, Blot WJ, Malker BK, Stone BJ, Weiner JA, et al. Occupational risks for intracranial gliomas in Sweden. JNCI 1987;78:253—7.
15. McLaughlin JK, Thomas TL, Stone BJ, Blot WJ, Malker HSR, Weiner JA, et al. Occupational risks for meningiomas of the CNS in Sweden. J Occup Med 1987;29:66—7.
16. Malker HSR, McLaughlin JK, Weiner JA, Silverman DT, Blot WJ, Ericsson JLE, et al. Occupational risk factors for nasopharyngeal cancer in Sweden. Br J Ind Med 1990;47:213—4.
17. Hall NEL, Rosenman KD. Cancer by industry: analysis of a population-based cancer registry with an emphasis on blue-collar workers. Am J Ind Med 1991; 19:145—59.
18. Wingren G, Axelson O. Mortality pattern in a glass producing area in SE Sweden. Br J Ind Med 1985;42:411—4.
19. Mantel M, Haenszel W. Statistical aspects of the analysis of data from retrospective studies of disease. JNCI 1959;22:719—48.
20. Miettinen OS. Estimability and estimation in case-referent studies. Am J Epidemiol 1976;103:226—35.
21. Phillips AN, Smith GD. How independent are "independent" effects? Relative risk estimation when correlated exposures are measured imprecisely. J Clin Epidemiol 1991;44:1223—31.
22. Andersson L, Wingren G, Axelson O. Some hygienic observations from the glass industry. Int Arch Occup Environ Health 1990;62:249—52.
23. Lüdersdorf R, Fuchs A, Mayer P, Skulsuksai G, Schäcke G. Biological assessment of exposure to antimony and lead in the glass-producing industry. Int Arch Occup Environ Health 1987;59:469—74.
24. von Schaller KH, Weltle D, Schiele R, Weissflog S, Mayer P, Valentin H. Pilotstudie zur Quantifizierung der Bleieinwirkung in der Keramische und Glas-industrie. Zentralbl Arbeitsmed 1981;31:442—52.
25. von Raithel HJ, Mayer P, Schaller KH, Mohrmann W, Weltle D, Valentin H. Untersuchungen zur Nickel-exposition bei Beschäftigten in der Glas-industrie. Zentralbl Arbeitsmed 1981;31:332—9.
26. Seidman H, Selikoff IJ, Hammond EC. Mortality of brain tumors among asbestos insulation workers in the United States and Canada. Ann NY Acad Sci 1982; 381:160—71.
27. International Agency for Research on Cancer (IARC). Chromium, nickel and welding. Lyon: IARC, 1990. (IARC monographs on the evaluation of carcinogenic risks to humans; vol 49)
28. International Agency for Research on Cancer (IARC). Overall evaluation of carcinogenicity: an updating of IARC monographs, volumes 1 to 42. Lyon: IARC, 1987. (IARC monographs on the evaluation of carcinogenic risks to humans; suppl 7.)
29. Andjelkovich DA, Mathew RM, Yu RC, Richardson RB, Levine RJ. Mortality of iron foundry workers: II. analysis by work area. J Occup Med 1992;34:391—401.