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LUNG CONTAMINATION OF WORKERS EXPOSED TO DUST WITH AN IRON COMPONENT

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ABSTRACT

Quantitative measurements of lung contaminants *in vivo* were made in 61 mild-steel arc welders, 68 stainless steel welders (both MMA and TIG), 10 foundry workers and eight crocidolite asbestos sprayers. The measurement was based on the measurement of the magnetic components of the retained dust, which served as a "tracer" when the total amount of dust was estimated. The estimated amount of the retained dust varied from 5 mg in asbestos sprayers to 1 000 mg in mild-steel arc welders. The interindividual variation in the amount of lung contaminants was very high. In mild-steel welders and foundry workers a good correlation between the retained lung contaminants and the radiological findings was observed. The threshold in the radiographs corresponded to an average magnetic field of 1 nT. The lung contaminants tended to deposit in the central areas of the lungs with two concentration centres in each lung. The conclusions regarding pathogenesis, the health hazards caused by inhaled aerosols in each group of workers, and the dose-effect relationship would require more extensive data than those provided by this preliminary study, and follow-up studies are needed as well.

With a recently developed method it is possible to determine quantitatively *in vivo* several lung contaminants in persons exposed to dust with a magnetic component[2,3,4,7,12]. Estimating the lung exposure of workers exposed to various metal aerosols is important for the following reasons: the respiratory tract is the most important route of entry for such pollutants; particles are small enough to achieve alveolar level and most particles are insoluble; therefore the lungs are the real target for such pollutants.

The aim of this study was (a) to evaluate clinical applicability of the magnetic measuring method to mild-steel and stainless stell welders, foundry workers and crocidolite asbestos sprayers and (b) to determine the amount of dust retained in the lungs of these workers.

SUBJECTS

Some characteristics of the subjects and their exposure are presented in Tables 1 and 2.

TABLE 1
Age and exposure time (years). About 45% of each group were smokers.

Occupational group	N	Age		Exposure	
		mean	S.D.	mean	S.D.
A. Mild-steel arc welders	52	39	10	14	7
B. Stainless steel welders	68	36	10	13	8
1. TIG (≤10% MMA)	18	36	10	13	10
2. "Mixed" (11–49%MMA)	15	37	11	10	4
3. "Mixed" (50–89%MMA)	15	33	11	10	5
4. MMA (≥90% MMA)	20	40	11	19	11
C. Foundry workers	10	58	6	33	7
D. Crocidolite asbestos sprayers	8	43	7	12 4*	6 2*

MMA = Manual Metal Arc
*years of non-exposure

Mild-steel welders

Sixty-one mild-steel arc welders from two shipyards and 10 controls were examined. A detailed description of these groups is presented elsewhere[7,8].

Stainless steel welders

During this study, 68 MMA (manual metal arc) and TIG (tungsten inert gas) welders from eight workplaces were examined (Table 1). As most of the subjects used both the MMA and the TIG welding process, the subjects were divided into groups according to the percentage of time spent doing MMA welding during the last ten years.

Foundry workers

Ten workers from an iron foundry were examined. Their occupations represented typical foundry jobs, e.g. molding, core making, fettling, annealing of casting, melting and casting. One subject was exposed only to core sand dust. The others had a mixed exposure to sand dust and metal fumes, which, for three, included the metal dust from grinding operations.

Crocidolite asbestos sprayers

The eight crocidolite asbestos sprayers included in the study worked either in a shipyard or in buildings. They sprayed only crocidolite asbestos as insulation material. All of them were diagnosed as having asbestosis and received compensation for having an occupational disease.

TABLE 2
Characteristics of exposure.

Occupational group	Typical concentration of respirable dust (mg/m³)	Particle size (mass median diameter) µm	Properties of particles
A. Mild-steel arc welders	2–200	0.3	Inert metal (?), (Fe 20–70%) Round particles with amorphous shell Siderosis, chronic nonspecific lung diseases?
B. Stainless steel welders 1. TIG (≤10% MMA) 2. "Mixed" (11–49%MMA)	1–8	0.01	Asthma (?) Mutagenic, carcinogenic (?) (Ref. 14) Cr 3%, Ni 1%, (Fe 70%) (Ref. 16)
3. "Mixed" (50–89%MMA) 4. MMA (≥90% MMA)	2–20	0.1	Metal particles without amorphous shell Cr 4%, Ni 0.5%, (Fe 6%) (Ref. 14)
C. Foundry workers	Examples 2.6 (coremaking) 6.8 (fettling) (Ref. 13)	0.1–1.0 (–10?)	Sand dust, metal fumes, metal dust Silicosis(?), siderosis, chronic nonspecific lung diseases Carcinogenic (?)
D. Crocidolite asbestos sprayers	Fibers (> 5 µm) 170–320 f/m² (Ref. 6)	–	Asbestosis Carcinogenic (Ref. 5)

METHODS

Clinical examination

The following set of examinations was carried out:

1. A clinical examination, including a detailed occupational history, was performed by the same physician in all cases. Respiratory symptoms were evaluated according to the MRC standardized questionnaire[11].
2. Laboratory tests: routine laboratory tests (blood haemoglobin, MCH, MCHC, erythrocyte sedimentation rate, leucocyte differentation counting, urine albumin and glucose); immunologic and allergic tests (total IgE, total eosinophils, skin tests, Prick method[1] (for stainless steel welders only), antinuclear antibodies, complements (C_3 and C_4) and alpha$_1$-antitrypsin; urinary chromium and nickel[15] (for stainless steel welders only).
3. Lung function tests: spirometry, flow volume curves, transfer factor (carbon monoxide single breath method), closing volume (helium method) and histamine provocation test (for stainless steel welders only).
4. Chest radiographs (antero-posterior and lateral 350 × 350 mm) interpreted and graded by two radiologists.

Measurement of lung contamination

The amount and distribution of retained lung contaminants were determined with a previously described method[2,4,7,9]. The method is based on the measurement of the magnetic components of the retained dust, which serves as a "tracer" when the total amount of dust retained in the lungs is determined. Figure 1 shows the measuring instruments.

FIG. 1 – Measuring instrument.

RESULTS

The measured average magnetic fields and estimated equivalent amounts of retained lung contaminants are presented in Figure 2. The estimated amount of the retained dust varied from 5 mg in asbestos sprayers to 1 000 mg in mild-steel arc welders. The interindividual variation in the amount of lung contaminants in each group was very high, even though the subjects worked under very similar conditions, e.g. in the same shipyard.

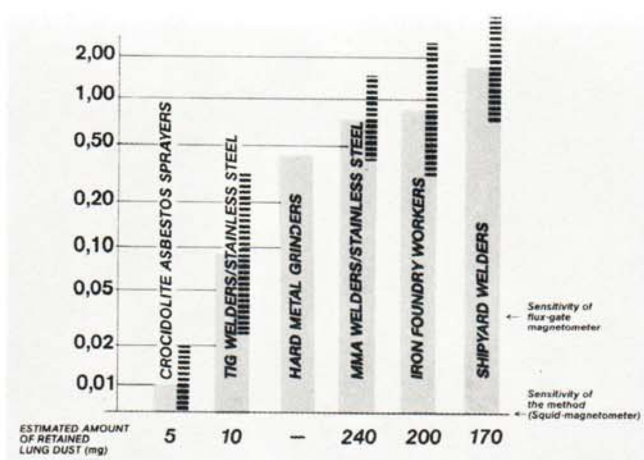

FIG. 2 – Average magnetic field and estimated equivalent amount of retained lung contaminants in different groups of workers.

In mild-steel welders and foundry workers a good correlation between the retained lung contaminants and the radiological findings was observed. The threshold in the radiographs corresponded to an average magnetic field of 1 nT.

The lung contaminants measured tended to deposit in the central areas of the lungs. There were two concentration centres in each lung; a variation in antero-posterior distribution was observed.

Mild steel welders

For the studies of lung retention and clearance under continuous exposure shipyard welders served as suitable subjects because their exposure was homogeneous. According to the results obtained the retention and clearance rates seemed to be balanced after five years of continuous exposure[10].

Stainless steel welders

A summary of the clinical findings of stainless steel welders is presented in Table 3. Preliminary results indicate that a large number of subjects have an atopic constitution. The most prominent respiratory symptom was chronic

TABLE 3

Clinical findings among stainless steel welders. Figures indicate average values for all welders, or for subgroups where a significant ($p < 5\%$) trend exists.

	Subjects with findings N	Subjects with findings %	Subgroups 1(TIG) N = 18	Subgroups 2 N = 15	Subgroups 3 N = 15	Subgroups 4(MMA) N = 20	Referent values
Atopic status							
skin test positive	34	50					
serum IgE, U/ml	40						< 10
Respiratory symptoms							
cough	9	13					
phlegm	22	32					
dyspnea, grade I–III	6	9					
recurring bronchitis	18	27					
chronic rhinitis	31	46					
Laboratory tests							
routine tests			normal	normal	normal	normal	
C_3(g/l)			1.37	1.37	1.44	1.50	0.55–1.40
C_4(g/l)			0.23	0.23	0.23	0.23	0.12–0.30
$alpha_1$-antitrypsin (g/l)			1.9	1.9	2.2	2.4	1.3 –2.1
urinary chromium (µg/l)			5	6	9	26	< 5
"urinary nickel"			2	2	3	6	< 1
Lung function tests							
VC, FEV_1, FEV%				normal			
$\dot{V}$max 25, % of predicted			107	99	84	92	
closing volume (%VC)			17	19	19	22	
transfer factor			normal	normal	normal	normal	
Radiological findings							
siderotic changes							
grade 0	21	30					
grade 1	30	45					
grades 2–3	17	25					
nonspecific							
grade 0	43	63					
grade 1	11	16					
grades 2–3	14	21					

rhinitis (49%), which may be partly due to the allergic status of the subjects, but which might also be due to a mechanical irritation caused by welding fumes. The values of complement C_3 and $alpha_1$-antitrypsin were increased in all groups. These parameters tended to increase as the percentage of time spent in MMA welding increased. The same trend was also observed for the lung function tests, i.e., a slight deterioration occurred as the usage of MMA increased.

The measured average magnetic field ($\overline{B}$) and urinary chromium and nickel values are presented in Figure 3.

The estimated amount of the retained dust average about 10 mg for TIG welders and 600 mg for MMA welders. A good correlation existed between long-term exposure ($\overline{B}$/nT), and short-term exposure (urinary Cr and Ni).

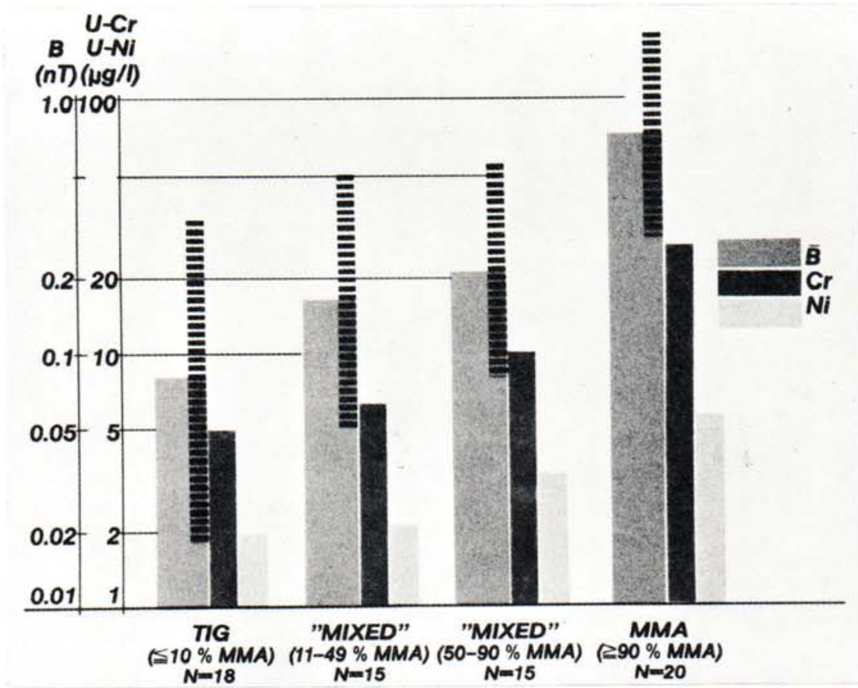

FIG. 3 – Average magnetic field and urinary chromium and nickel values in different groups of stainless steel welders.

The radiological changes were in all cases discrete, but it was possible to grade them in three categories, 1 – 3. The chest films were interpreted critically and disturbing facts such as old inflammatory changes were taken into consideration. Further studies are needed in order to establish the exact character of the lesions.

Foundry workers

The clinical findings of the foundry workers are summarized in Table 4. Dyspnea, grade II – IV, was the most prominent respiratory symptom in this group. The grade of dyspnea correlated rather well with the lung function test results, the best correlation being found for transfer factor ($r = -0.78$).

An attempt was made to differentiate the radiological changes caused by quartz and metal particles as can be seen from Table 4. The changes encountered seemed to be foremostly caused by the metal dust.

The radiological findings indicating "siderotic" and "silicotic" changes correlated ($r = 0.62$) with dyspnea stage.

The mean value of the measured average magnetic field was 0.8 nT (range 0.1 – 8 nT), and the typical amount of the retained contaminants was 200 mg

TABLE 4

Clinical findings and lung contamination among foundry and asbestos workers.

	Foundry workers	Asbestos workers
Respiratory symptoms present, number of subjects with:		
cough	4 (40%)	1 (12%)
phlegm	1 (10%)	4 (50%)
dyspnea, grade II–IV	9 (90%)	6 (75%)
Lung function tests		
VC (% of predicted	91	55
FEV_1 (% of predicted)	93	49
transfer factor (% of predicted)	87	69
Radiological findings, number of subjects with:		
siderotic changes		
grade 0	– –	
grade 1	5 (50%)	
grade 2	4 (40%)	
grade 3	1 (10%)	
silicotic changes		
grade 0	5 (50%)	
grade 1	3 (30%)	
grade 2	2 (20%)	
grade 3	– –	
pneumoconiosis, ILO/VC/1971		
grade 0		2 (25%)
grade I		5 (63%)
grade II		1 (12%)
Magnetic measurement		
average magnetic field (nT)	0.81	0.01
amount of dust (mg)	200	5

(range 30–600 mg). Both "siderotic" and "silicotic" radiological findings correlated with the measured average magnetic field.

Crocidolite asbestos sprayers

The clinical findings of these subjects are summarized in Table 4, and indicate a moderate degree of asbestosis in most subjects. The typical average magnetic field was 0.01 nT (range 0.00–0.02 nT), and the estimated amount of the retained asbestos was roughly 10 mg. The measured magnetic signals were so low in this group that the measurement was difficult to perform.

DISCUSSION

In this study four groups of workers were examined which represented exposure to metal aerosols in different occupations. Shipyard welders were chosen because of their homogeneous exposure, which aided the study of lung retention and clearance rates under continuous exposure. Stainless steel welders formed a heterogeneous exposure group in that welders use several welding techniques. The asbestos sprayers studied formed another homogeneous exposure group. The last group, that of foundry workers, was selected to represent all typical occupations, because the properties of foundry dust differ from one foundry occupation to another.

In addition to determining the average amount of retained lung contaminants for each group, we gained an insight into the lung contaminant distribution. The estimated amount of lung contaminants in the groups differed by more than one decade. The content of lung dust was lowest in asbestos sprayers and highest in shipyard welders. This variation was due to the differences in exposure and perhaps also to different deposition and clearance rates. Determining the correlation between the retained lung content and the concentration of inhaled pollutants would require systematic follow-up studies.

The radiological findings and the amount of contaminants could be correlated for the mild-steel arc welders and foundry workers. The conclusions regarding pathogenesis, the health hazards caused by inhaled aerosols in each group and the dose-effect relationship would require more extensive data than are provided by this study, as well as follow-up studies.

In future research at least the following factors must be taken into consideration:

- subjects (exposed to metal dust or fumes);
- respective metal dusts and fumes in inhaled area, especially their physical and chemical properties and their mutagenicity and carcinogenicity *in vitro;*
- post-mortem studies of lungs and other organs tissue changes, distribution and amount of contaminants, immunologic findings in tissues, shape and size of contaminants;
- animal experiments.

This approach might produce information on the following:

- real exposure of man;
- interaction mechanism of contaminants in biological tissue;
- lung retention and clearance rates under continuous exposure;
- health hazards;
- dose-response relationships;
- influence of the physical and chemical properties of dust on toxicity.

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