

Occupational Exposure During Asbestos Removal Operations

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Abstract

Workplace protection factors (WPFs) were determined for a mask used successively with four different power units during the removal of sprayed asbestos in a building. These WPFs were determined for workers dressed with waterproof overalls especially designed in order to guarantee tightness. Difficulties in the decontamination phase of the respiratory protection devices were pointed out, particularly for two power units. The WPFs ranged from 400 to 10,000, with most values greater than 3000. No satisfactory explanation was found for the poorest results: the test procedure was identical in all cases, and no particular incident was pointed out during the assessment.

Introduction

Removal or encapsulation of asbestos-containing materials is likely to expose workers to atmospheric concentrations of pollutant well beyond the limit-values. The use of respiratory protection is necessary. Even so, it still must be ensured that the protection provided to the worker will be sufficient in conditions of actual use. For example, recent papers by Wallis et al. (1993) and Hery et al. (1993) have shown that the efficiency of negative pressure half-masks in real working conditions was, in some cases, well below the value which could be expected based on laboratory tests.

Specific recommendations on the choice and maintenance of respirators, and worker training have been put forth for asbestos (for example Beddows, 1984). However, few studies have been conducted in order to assess the exposure of workers protected by respirators. Among these, Cuendet and Bilat (1984) tested a negative pressure full mask of which the workplace protection factor (WPF) was found to range from 20 to 250 depending on the individual user, where the

workers were exposed to chrysotile at levels from 0.01 to 0.03 fibers/cm³ (f/cm³). The term of WPF might be somehow excessive because it does not seem that any fit testing had been performed by the subjects before the study. A similar study was performed by Akkersdijk et al. (1989), essentially on crocidolite (and varying amounts of amosite and chrysotile), using powered respirators with a WPF of about 350 (arithmetic mean) and exposures ranging from less than 0.01 to 0.13 f/cm³. It must be pointed out that these results were obtained after the equipment had been significantly modified in order to make it suitable for the task performed by the workers; initial results were less favourable. No fit testing seems to have been performed in this study either.

Our laboratory was asked to assess the exposure of workers involved in the removal of sprayed asbestos in an office block. This demand was made by a firm specialized in asbestos stripping in buildings. Because of its knowledge in the difficulty of assuring the protection of its employees in

such activities, the specialized firm wanted to test specific equipment in order to determine the most practical and the most efficient.

About a dozen male workers of the specialized firm were concerned by the test. They routinely

used the protective clothing (including respirator) tested in the present study. Each worker was asked to perform 2 or 3 efficiency tests for different power units.

Working Methods—Materials

Asbestos Removal Method

In a first step the asbestos-containing material (chrysotile and glass fiber) was impregnated with a solution containing a polymerization agent in order to make the unsticking of the material easier and to reduce the generation of fibers. This solution was applied with a spray gun. After this impregnation the material was manually removed using a spatula. In spite of the impregnation, this operation obviously generates large amounts of atmospheric asbestos fibers. Consequently, the workplace had to be isolated from the external environment. For that purpose a special decontamination room was installed, where one passed through five successive airlocks especially designed for (un)dressing, and showering (of body or of clothes). Each airlock was isolated from its neighbours by the means of staggered heavy polyethylene films. This decontamination room and the corresponding operations are described in Figure 1. Asbestos waste was packed in plastic bags.

Personal Protective Equipment

The workers wore special Goretex® waterproof overalls, composed of trousers and a windbreaker, of which the tightness to the wrists and the ankles was especially checked. A specific clamping ring was fixed on the windbreaker hood in order to guarantee the perfect tightness of the windbreaker-full face piece mask joint.

The full face piece mask (Societa Generale Elastomeri, model SGE 400 F) was connected to a power unit. Four different models of power units were tested, of which the nominal mean air flows are given in Table I. These values are furnished by the manufacturers for material in good working order; i.e., what the models tested in the study were supposed to be since they were new. No control was performed by our laboratory. The value of the air flow provided by the power unit is very important because NIOSH (National Institute for Occupational Safety and Health) (1983) considers that no Assigned Protection Factor (APF) of

more than 50 can be assigned to respiratory protection devices in which negative pressure can occur. In the case of a supplied-air respirator equipped with a full facepiece and operated in a pressure demand or other positive pressure mode, values of 2000 can be reached.

The filters carried at the belt near the power unit of the respirators were changed daily. Only P3 filters were used. According to a European standard (Comité Européen de Normalisation [CEN] [European Standards Committee] 1989) these filters are the most efficient, with an initial maximum penetration of 0.2 % for solid aerosols, and 0.1 % for liquid aerosols. A diagram of the powered air supply system and the mask is given in Figure 2.

Air Sampling

Air was sampled simultaneously inside and outside the respirators in order to determine the protection factor. The sampling was performed on 25 mm mixed cellulose ester membrane filters (Millipore AAWG0250C, 0.8 μ m pore size) contained in open-face Delrin® filter holder, connected by PVC (polyvinyl chloride) tubing to air sampling pumps (Gilian HFS 113) of which the flow rate was measured before and after the test with an electronic bubble flowmeter (Giliblator). According to the corresponding French standard (Association Française de Normalisation [AFNOR] [French Standards Association] 1991), the flow rate ranged from 0.5 to 2.0 l/min. The lowest and highest flow-rates were used for outside and inside samplings respectively. In spite of this difference in air flow and because of the respective levels in dust concentration inside and outside the respirators, it was necessary to successively sample several filters outside for only one filter inside. The total sampling time for each test ranged from 3 to 6 hours. The sampling time was mainly determined by the task performed and the airborne fibers concentration generated, i.e., by the rough estimation that the filter sampled inside the mask would be loaded enough to allow us a satisfactory fiber count.

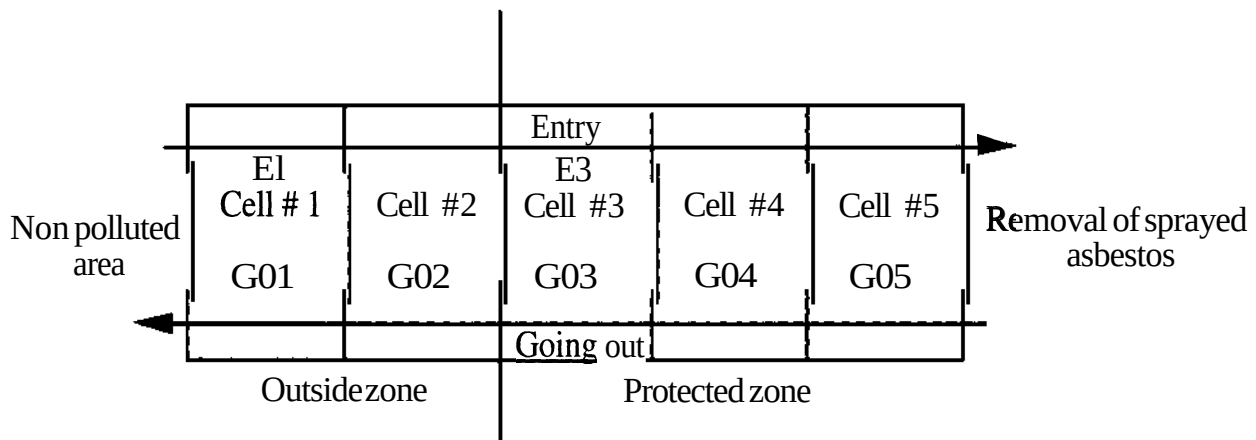


Figure 1. Diagram of the decontamination room.

E1	Undressing (bathrobe)
E3	Dressing (overalls)
G05	Storage of polluted tools
G04	Overalls and respirator shower (used filters are put back into cell # 5)
G03	Storage of overalls and respirator
G02	Body shower
G01	Dressing (bathrobe)

Because of the requirements of the French standard, sampling had to be performed with filter holders in open-face configuration. Consequently no sampling probe was used and the filter holder was put directly inside the mask, special care being taken to ensure the air tightness of the mask in spite of the passing of the filter holder through the mask. It can be seen in Figure 2 that the filter holder was closer to the worker's forehead than to his nose and mouth. Because of the open face configuration it was impossible to choose what would have been the most convenient location because no filter holder in open face configuration could have been introduced in the rubber snout which covers the mouth and nose of the worker inside the mask. Nevertheless, even if it cannot be said that the sampling location is the most representative of the exposure of the worker, it is situated (as shown by the arrows indicating the air flow streams) in the volume where the air filtered

by the power unit fitted with the P3 filter enters the mask. All inside samples were taken at the same location, making possible a comparison between the different tests.

Fiber Counting

According to the French standard previously quoted (Association Française de Normalisation 1991), the determination of the number of fibers was made by phase contrast optical microscopy. Only the fibers of which the length was greater than 5 μm , the width less than 3 μm and the length to width ratio of 3 or greater were counted. Using this method, other non-asbestos fibers (especially glass fibers) may be taken into account. As a consequence the French limit value for chrysotile (0.6 f/cm^3) was used regardless of the nature of the fiber.

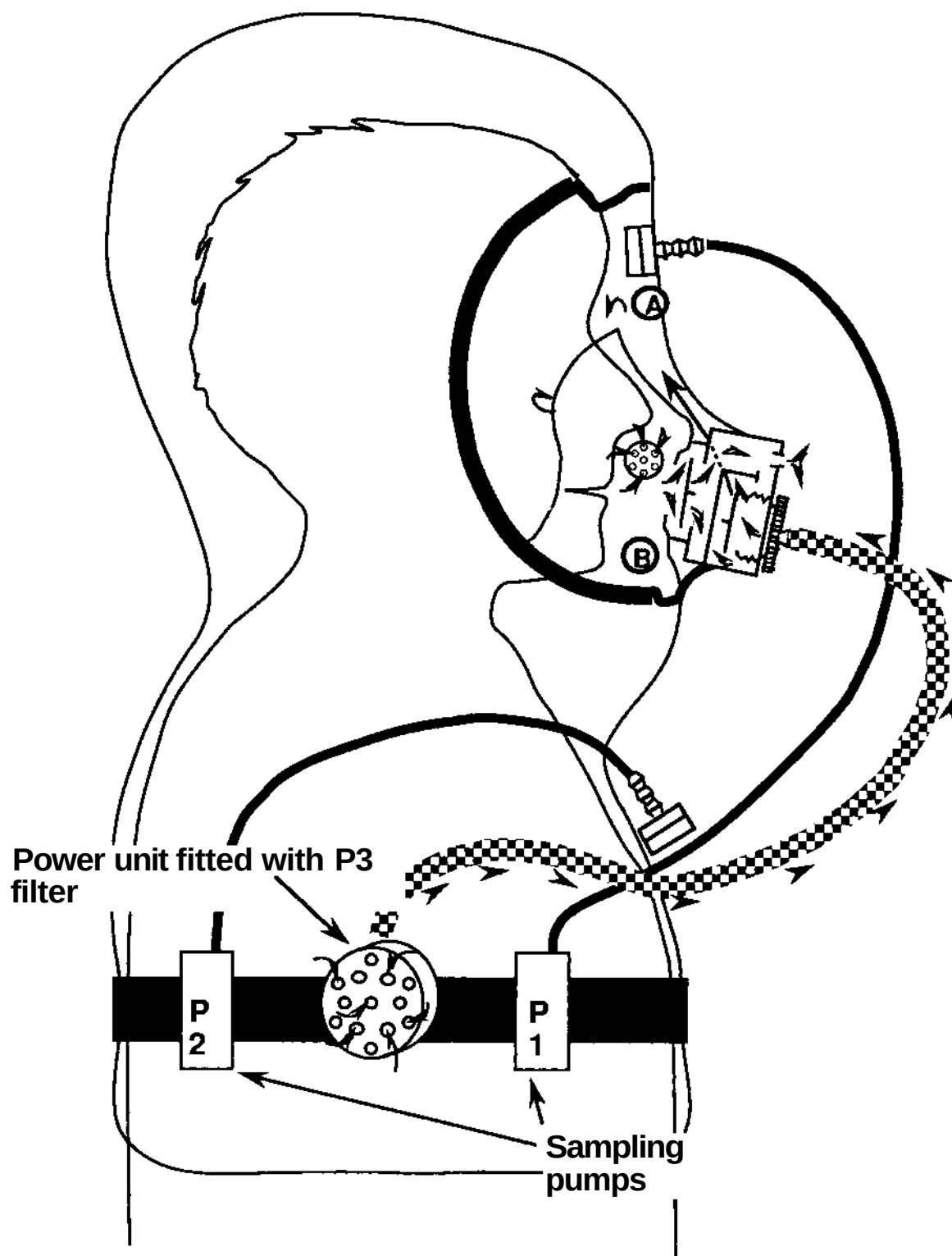


Figure 2. Diagram of the powered air supply system and sampling method.

Results

The test which initially had been arranged in order to compare the performances of 4 different power units (referred to by the letters A to D in this paper) used with the same full face piece mask, was rapidly restricted to two models, and then one. The use of models B, D and A had to be limited for different reasons.

Power Unit B

This power unit had theoretically the highest nominal flow rate (250 l/min). It had to be discarded after an initial test because the flow rate reached the limit value (180 l/min) during this test, at which point a warning signal sounded. Exterior charging of battery did not allow the equipment to reach a flow rate superior to that limit value, even though the power unit was brand new.

Power Unit D

No flow rate problem was found for this power unit, but problems arose during the decontamination phase. In order to avoid the dissemination of asbestos outside the workplace, special procedure for entering and leaving the working zone was established. The principle of this procedure is given in Figure 1. It required that the respiratory protective devices (mask and power unit) and the protective clothing be handled outside of the protected zone, which meant that all of them had to be decontaminated after each test, and in particular showered off. It was not possible to do this with power unit D which was not designed for such a purpose. It had to be decontaminated in a special way, including the use of a special protective dust sheet. Because of these constraints power unit D was not easy to routinely use, and only two tests were performed on this model.

Power Unit A

Decontamination under the shower was possible with power unit A only if very strict precautions were taken. Taking these precautions was rapidly found too exacting for both workers and our team and few tests were therefore performed on this model.

Power Unit C

Only power unit C was designed in a satisfactory way for the particular case of asbestos removal. Most tests were performed with this model, which was routinely used by the specialized firm.

In spite of the precautions taken (shorter sampling time, lower sampling flow rate) many samples collected in the atmosphere of workplace, i.e., outside the respirators, could not be counted because of the excessive loading of the filter. Half of the tests had to be cancelled because of sampling incidents, most of them due to a moistening of the inside filter under the decontamination shower, or following the undressing of the worker. The inside filter was sampled correctly and recovered in a satisfactory way (i.e., without moistening during the decontamination shower of the protective equipment) in only 15 tests. Among these 15 tests, the outside concentration could be correctly assessed in only 10 cases. The results of the 15 tests are given in Table 2. The mean fiber concentration outside mask is a time weighted averaged value, i.e., a value which takes into account the sampling times of the different values in order to determine the mean value. For the determination of fiber concentration inside mask, only one sample was taken.

Discussion

The main result of this series of tests is that all of the occupational exposures measured inside the respirator are below the limit value of chrysotile. Among these results, the 9 results obtained with power unit C, 1 (out of 3) with power unit A and 1 (out of 2) with power unit D are at values equivalent to 1 or 2 % of the limit value.

The concentrations of the remaining samplings

are appreciably higher: 20 to 50 % of the limit value. All the tests having been performed under identical conditions (the way in which individuals wore their masks, the fixing of the full face piece mask, the air filtering), the differences observed here are likely to be explained by a momentary pressure drop inside the respirator. This pressure drop might be due either to an insufficient air flow

provided by the power unit (it might be the case for power unit B of which the working was not satisfactory at the end of the test) or to an important breathing demand of the worker corresponding to a physically exacting task.

Because of the difficulties encountered in the assessment of the external asbestos concentration, it was not possible to determine the protection factor provided by all the devices. If we consider only power unit C, for which the measurements are the most numerous, the protection factor ranges from 400 to 10000, with most values greater than 3000. These values are rather higher than those found by Akkersdijk (1989) in similar conditions (outside concentrations, workers' clothing and working zone isolation). In one set of circumstances measured by Akkersdijk, the WPF (arithmetic mean, 4 tests) increased from 60 to 350 when new measures were taken, including replacement of the power unit filters every day instead of every week, replacement of partially permeable protective clothes with more satisfactory ones, and cleaning of the changing facility every week (no real decontamination room was available). At a second job site described by Akkersdijk, where the decontamination process was slightly improved, the WPF was also near 350 (arithmetic mean, 5 tests). The difference between the WPF measured in our study and the WPF measured by Akkersdijk might be due to the decontamination process which insured in our study that the workers dressed in clothes that were completely free of asbestos in a place which was also asbestos free.

This experiment showed that it is possible to reduce the exposure of workers involved in asbestos removal to very low levels, at the cost of supplying specially designed equipment (waterproof

clothing and respirator). It is also remarkable that although the inside concentrations differed by as much as a 50-fold factor, we did not notice any difference between test 2 (with power unit A) and tests 11, 12 and 13 (with power unit C) during the sampling. In both cases the same P3 filter, the same mask, the same clothes were tested in outside concentrations reaching the same level. Moreover power units A and C are reputed to have the same nominal air flow, and no difference was observed in the task performed (for example, one power unit might have been tested in more physically exacting working conditions, but it does not seem to have been the case).

In the case described in this study, this poorer efficiency of power unit A was of relatively no consequence because of the nature of the asbestos (chrysotile), the mixed character of the material (asbestos and glass fiber), and the great care taken in respecting the proscribed procedures

((un)dressing, entry and leaving the site). It was however shown that the concentration inside the respirator may increase dramatically when an incident happens (whatever it may be).

Some results obtained in the course of this study, which are acceptable in the conditions described here, would clearly be insufficient in certain circumstances, for example in the case of the removal of sprayed pure crocidolite insulation. In such a case the limit value (0.3 f/cm^3 in France, 0.2 f/cm^3 in the United States according to the list of the ACGIH [American Conference of Governmental Industrial Hygienists]) would be exceeded. It is important to identify exactly which problems in the personal protection are responsible for the differences of efficiency encountered during this study. More tests will be performed.

Power unit	Mean air flow (l/min)
A	140
B	250
C	150
D	160

Table 1. Characteristics of the power units tested.

Power unit/Test #	Fiber concentration ^a inside mask (f/cm ³)	Mean fiber concentration outside mask (f/cm ³) ^a	Workplace Protection Factor
A/1	0.157	21.4	140
A/2	0.318	> 70	> 220
A/3	0.011	0.98	90
B/4	0.097	n.d.	/
C/5	< 0.007	0.073 ^b	/
C/6	0.007	n.d.	/
C/7	0.009	3.5	400
C/8	0.006	n.d.	/
C/9	0.006	25.7	4300
C/10	< 0.006	19.5	> 3300
C/11	< 0.007	> 70	> 10000
C/12	0.019	> 70	> 3700
C/13	< 0.024	> 70	> 3000
D/14	< 0.022	n.d.	/
D/15	0.283	n.d.	/

n.d. : not determined, filters overloaded

a : $L > 5 \mu\text{m}$, $D < 3 \mu\text{m}$, $L/D > 3$

b : no work performed

Table 2. Outside and inside concentrations of fibers during efficiency tests.

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