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To assess the magnitude of fiber emission from asbestos gloves, 10 pairs were compared in an isolation chamber during simulation of a sterilization procedure; 176 air samples were collected. Means of time weighted average (TWA) concentrations ranged from 0.95 to 11.74 fibers (>5 μm)/cm^3 of air. Well-worn/clean gloves emitted significantly more fibers than did brand-new gloves, but fiber emission decreased with increased surface soiling. Eighty air samples were collected during simulation of the sterilization procedure in a well-ventilated room. The range of mean TWA concentrations was 0.07-0.99 fiber/cm^3 for breathing zone samples and 0.06-0.60 fiber/cm^3 for area samples. Thirteen samples were collected at actual workplaces; the range of TWA concentrations was 0.07-2.93 fibers/cm^3 for breathing zone samples and 0.04-0.74 fiber/cm^3 for area samples. Five of seven breathing zone samples from workplaces exceeded the proposed TWA concentration limit of 0.1 asbestos fiber/cm^3. Hand contamination also was assessed. Four samples collected after touching the worktable ranged from 9953 to 13 108 fibers (>5 μm)/cm^2 of hand surface area; seven samples collected immediately after taking off gloves ranged from 741 to 3860 fibers/cm^2. Available substitutes for asbestos gloves are discussed, and adoption of these substitutes is recommended strongly.

Occupational exposure to asbestos fibers resulting from use of asbestos gloves

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introduction

Although the health hazards of exposure to asbestos in various occupations have been well documented,[1-3] little attention has been given to the exposure of workers who wear asbestos gloves for handling hot objects. Asbestos gloves have been used commonly in hospital, industrial, and university laboratories where sterilization is done, and in hot industries such as foundries. A report on the similarity of asbestos fibers to a bacterial structure documented the contamination of electron microscopy grids with asbestos fibers after asbestos gloves were tossed onto a laboratory table.[4] However, a computer search of the literature, using six data bases, did not reveal any quantitative studies of fiber emission from asbestos gloves, or any discussion of possible exposure to asbestos via the respiratory or digestive tracts during use of these gloves.

Apparently, it has been assumed that wearing asbestos gloves does not expose workers to significant levels of asbestos fibers, and these gloves are still being used despite the availability of non-asbestos gloves with comparable heat resistance. However, any degree of exposure to asbestos is now considered to increase the risk of asbestos-related diseases such as mesothelioma, bronchogenic carcinoma, and digestive tract cancer. We have thus attempted to assess the health hazards associated with use of asbestos gloves by collecting personal and area air samples: 1) during simulated laboratory procedures in an isolation chamber and in a biology preparation room, and 2) during the actual work day of five workers in their laboratories. It was observed that the workers usually did not wash their hands after handling the gloves; therefore, experiments were included to estimate the extent of hand contamination during normal glove usage.

materials and methods

Eight pairs of asbestos gloves in actual daily use were collected from six microbiology and chemistry laboratories on two university campuses, and two new pairs were obtained from the UW-Parkside stockroom. All gloves were of the same type and were purchased from the same company. They were made from asbestos cloth which contained 80-85% asbestos and 15-20% rayon. The cloth was treated with an acrylate-based compound and thus was described as "lint-free." The gloves were classified into the following groups based on structural integrity and apparent surface cleanliness: Group A, well-worn/clean, four pairs; Group B, well-worn/lightly soiled, three pairs; Group C, well-worn/heavily soiled, one pair; Group D, brand-new, two pairs. Representative gloves from each of the four groups, A-D, are shown in Figure 1. To eliminate the effect of moisture, all gloves were kept in a dry incubator at 70 °C until tested.

A ventless isolation chamber was used to determine airborne fiber emission from the gloves under controlled conditions, during simulation of the operation used both for routine sterilization and for drying laboratory glassware. This operation consists of: 1) picking the gloves up from the table top and putting them on; 2) opening the autoclave or oven door; 3) removing a tray containing the media or glassware and setting the tray on the table top; 4) closing the door; 5) taking the gloves off and tossing them onto the table top. The experimenter carried out these five steps inside the chamber after inserting his arms through two portholes in the front panel. The interval between consecutive operations was 30 minutes, which represented a normal workload in UW-Parkside's media preparation room. Air samples were

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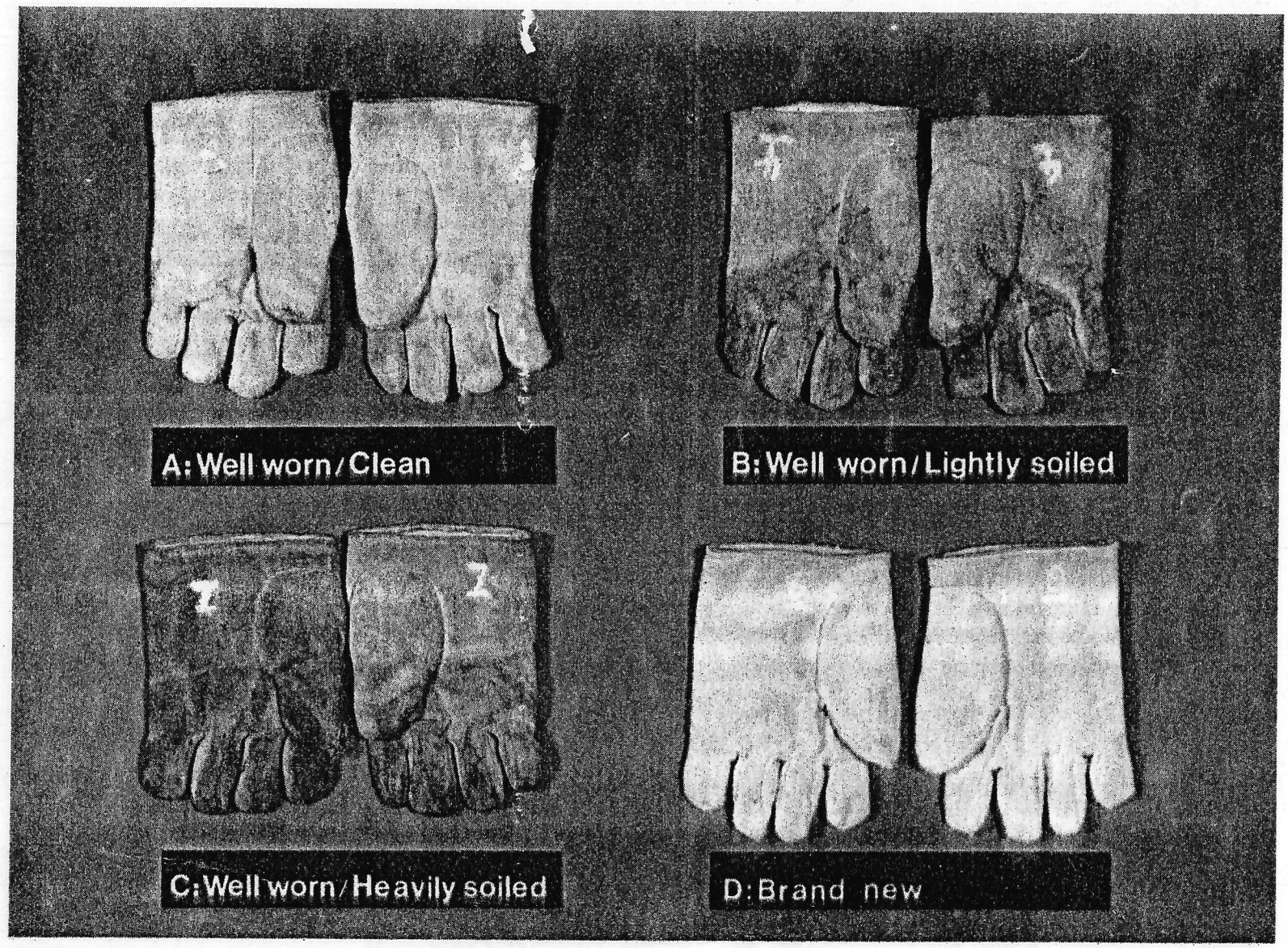


Figure 1 — Representative asbestos gloves from each of the 4 groups, A-D.

TABLE I
Concentration of Airborne Fibers (>5 μm) Emitted from Asbestos Gloves Tested in a Non-Ventilated Isolation Chamber

Gloves ID #	Condition of Gloves	No. of Samples	Conc. of Fibers/cm³ Mean ± SD
A1	Well-worn/clean	20	6.20 ± 2.36
A2	Well-worn/clean	20	5.82 ± 1.53
A3	Well-worn/clean	18	8.12 ± 2.90
A4	Well-worn/clean	20	11.74 ± 1.16
Overall for A Gloves:		78	7.97 ± 3.14 (Mean)
B1	Well-worn/lightly soiled	20	5.09 ± 0.86
B2	Well-worn/lightly soiled	20	5.12 ± 1.05
B3	Well-worn/lightly soiled	16	5.02 ± 1.89
Overall for B Gloves:		56	5.08 ± 1.27 (Mean)
C1	Well-worn/heavily soiled	18	0.95 ± 0.16
D1	Brand-new	24	2.25 ± 0.57

collected inside the chamber, processed, and counted using the methods recommended by NIOSH.[5]

The same sterilization operation was also simulated in a well-ventilated biology preparation room which had five air changes per hour. Air samples were collected both from the breathing zone of the experimenter and from the work area. The interval between consecutive operations was either 30 minutes to represent the normal workload, or 10 minutes to represent a heavy workload.

The biology preparation room also was used to assess possible exposure to asbestos through ingestion of fibers on hands. Contamination of hands from an approximately 0.6 m^2 (6 ft^2) work area of the laboratory table top was measured after an 8-hour simulated work shift with 16 uses of the gloves. The palm of one hand was touched to four different places 30 cm apart, in a line 15 cm in front of where the gloves were tossed. The fibers were removed from the contaminated hand after each contact by immersing the hand in a 2-L beaker containing approximately 1.5 L of distilled water, followed by flushing the hand with a wash bottle. The water was poured through a membrane filter of 0.45 μm pore size, and the filter was processed and counted using the methods recommended by NIOSH.[5] In a second experiment, the amount of asbestos remaining on either one or both hands, immediately after removal of the gloves from the hands, was examined by washing with water as described above. Each hand was washed separately when both hands were sampled, but the two portions of wash water were poured through the same filter to yield one sample. Hand surface area was determined by making tracings of pertinent surfaces of the hands on paper and measuring the areas with a planimeter.

In the studies performed on the workers in their actual workplaces, air samples were collected from the breathing zone of each worker and from an area 75 cm above the table top where the gloves were laid or tossed.

TABLE II
Comparison of Mean TWA Concentrations of Airborne Fibers Emitted from Asbestos Gloves Using *a priori* Analysis of Variance

Gloves Compared	F Ratio	Probability
A vs. B	109.4	≪0.01
A vs. C	290.4	≪0.01
B vs. C	93.8	≪0.01
A and B vs. D	83.8	≪0.01

results

One hundred seventy-six air samples were collected from the confined atmosphere of the isolation chamber during simulation of the sterilization procedure with asbestos gloves. The mean TWA concentrations of airborne fibers >5 μm shown by these samples ranged from 0.95 to 11.74 fibers/cm^3 (Table I). The minimum and maximum TWA concentrations observed were 0.61 fibers/cm^3 for gloves #C1 and 16.5 fibers/cm^3 for gloves #A3, respectively. The main factors influencing the magnitude of fiber emission seemed to be the

TABLE III
TWA Concentration of Airborne Asbestos Fibers (>5 μm) in Personal and Area Samples Collected During Simulation of Work With Asbestos Gloves in a Well-Ventilated Biology Preparation Room

		Breathing Zone			Work Area		
Gloves ID #	Work Load*	No. of Samples	Mean TWAC ± SD	F Test: A vs. D	No. of Samples	Mean TWAC ± SD	F Test: A vs. D
A2	Normal	8	0.49 ± 0.11	F=7.6 P<0.05	8	0.40 ± 0.09	F=4.56 P<0.05
A3	Normal	10	0.27 ± 0.18		10	0.20 ± 0.14	
D2	Normal	4	0.07 ± 0.02		4	0.06 ± 0.02	
A2	Heavy	5	0.99 ± 0.22	F=9.6 P<0.01	6	0.60 ± 0.12	F=28 P<0.01
A3	Heavy	6	0.74 ± 0.22		6	0.60 ± 0.18	
D2	Heavy	7	0.51 ± 0.21		6	0.26 ± 0.08	

*Normal and Heavy designate usage of gloves 2 times and 6 times per hour, respectively.

TABLE IV
TWA Concentration of Airborne Asbestos Fibers (>5 μm) in the Breathing Zone and Work Area of Laboratory Employees Using Asbestos Gloves

Sampling Location	Operation	Glove Usage /8 hr Shift	TWA Conc. of Fibers/cm^3 Breathing Zone	Work Area	Glove ID #
UW-Parkside Media Prep Room	Sterilizing in autoclave	14 times (Normal)	.70	.30 .74	B2
UW-Parkside Media Prep Room	Sterilizing in autoclave and drying glassware in oven	16 times (Normal)	.46	.67	B2
			.71	.51	B2
		36 times (Heavy)	2.93		A1
UW-Parkside Biology Lab	Killing rats in ether	48 times (Heavy)	.89		A1
Madison Lab 1	Drying glassware in oven	28 times (Heavy)	0.10	0.10	B2
Madison Lab 2	Sterilizing in 5 autoclaves	41 times (Heavy)	0.07	0.04	A4

structural integrity of the gloves, determined by age and/or extent of usage, and the degree of surface soiling. The mean TWA concentrations from the four groups of gloves were compared using *a priori* analysis of variance.[6] This test indicated that the differences observed between the means of TWA concentrations all were highly significant, with $p \ll 0.01$ (Table II). Well-worn/clean gloves emitted almost 3 times as many fibers as did brand-new gloves; however, the magnitude of fiber emission from well-worn gloves decreased with increased surface soiling. The mean TWA concentrations for lightly and heavily soiled gloves were, respectively, 0.6 and 0.1 the value for clean used gloves.

Results of 80 personal and area samples collected from a well-ventilated biology preparation room, during simulation of the sterilization procedure with gloves in Groups A and D, are presented in Table III. The TWA concentrations of airborne fibers were considerably lower than those obtained in the ventless isolation chamber, evidently due to

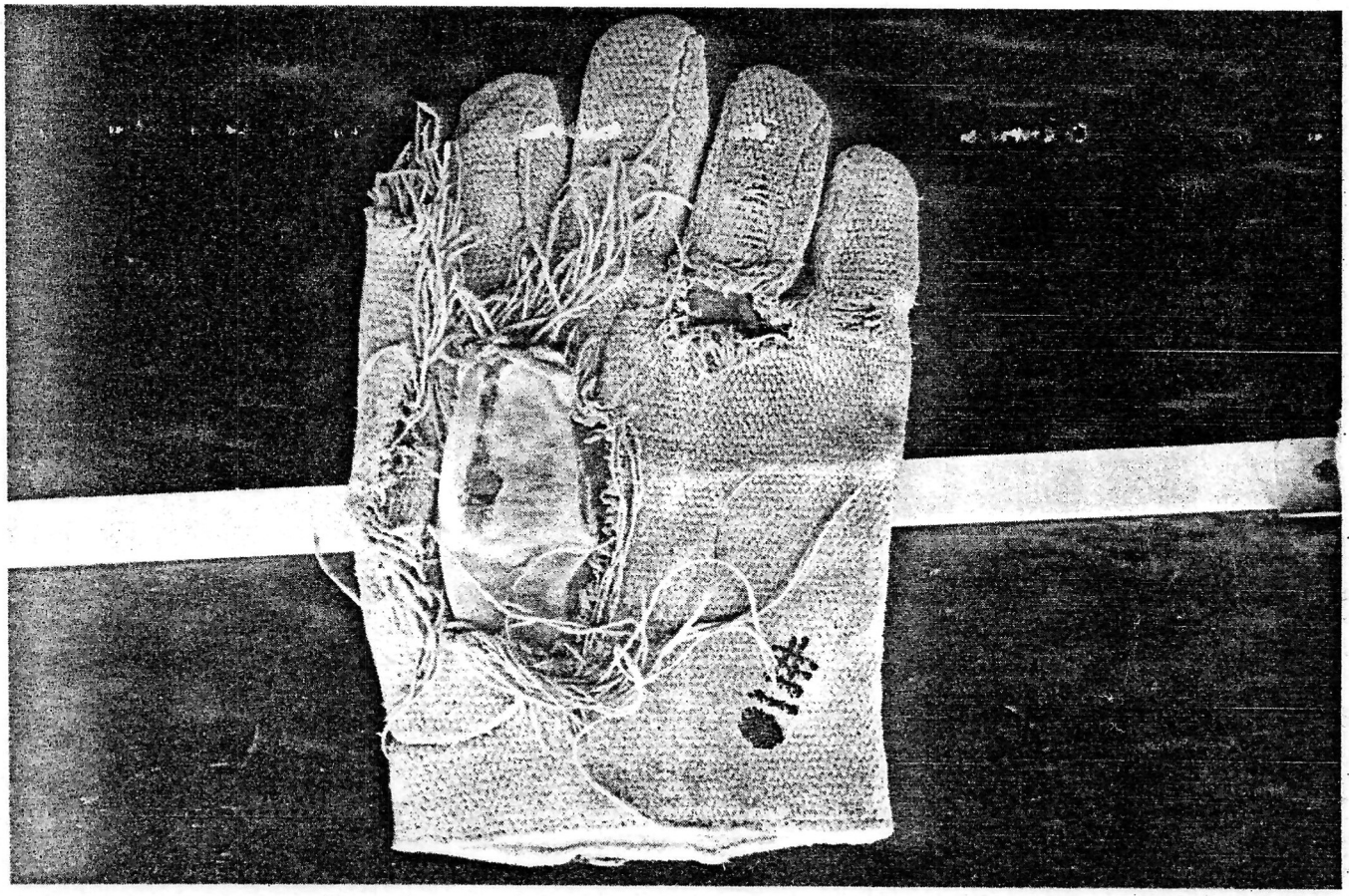


Figure 2 — An asbestos glove which was still in laboratory use.

the dispersion of fibers within the room by the ventilation system. The TWAC values for breathing zone samples ranged from 0.05 to 0.61 fiber/cm^3 with normal workload and from 0.27 to 1.25 fibers/cm^3 with heavy workload. Corresponding TWAC ranges for area samples were 0.02-0.52 and 0.15-0.81 fiber/cm^3, respectively. The mean TWA concentrations for Group A (well-worn/clean) gloves were compared with those for Group D (brand-new) gloves by analysis of variance. The F values shown in Table III confirm the findings in the isolation chamber that the well-worn/clean gloves emitted a significantly higher number of asbestos fibers into the atmosphere than did the brand-new gloves.

Thirteen personal and area samples were collected from the actual workplaces of five workers. Maximum and minimum TWAC values were 2.93 and 0.07 fiber/cm^3 for breathing zone samples and 0.74 and 0.04 fiber/cm^3 for area samples (Table IV). With this limited number of samples, it was found that exposure levels depended more on the particular laboratory than on glove condition and workload, which were the main influencing factors under the controlled conditions of the experiments shown in Table III. For example, although the UW-Parkside and Madison Lab 2 workers were performing similar operations with Group A gloves at a heavy workload rate, the TWAC of the UW-Parkside worker was 29 times that of the Madison worker. There was an efficient exhaust system over the row of five autoclaves in Madison Lab 2. Undoubtedly, differences in room size and arrangement, efficiency of the ventilation system, and amount of moisture on gloves would be important in determining relative exposures of workers using asbestos gloves in different laboratories.

Results from the hand contamination studies revealed significant numbers of fibers on the hands. Values for the four samples collected by touching the contaminated table, where gloves A3 had been tossed 16 times, ranged from 9953 to 13 108 (mean = 11 688) fibers (>5 μm)/cm^2 of hand surface area (palm side of hand). Values for seven samples collected from the hands immediately after removal of gloves A4 ranged from 741 to 3860 (mean = 1925) fibers/cm^2 of hand surface area (both sides of hands).

discussion and conclusion

The results of this study suggest that the use of asbestos gloves exposes the wearer to potentially hazardous levels of asbestos. In addition to inhaling airborne fibers, workers may ingest an indefinite number of fibers present in the air and on their hands and clothing.[7] The fibers are apparently easily dislodged from the gloves during handling, and remain on the hands after the gloves are removed. Evidence for entry of asbestos fibers by the gastrointestinal route, including evidence for and against actual penetration of the gastrointestinal wall, has been reviewed.[7] The authors concluded that "penetration must be postulated even though the proof is not yet conclusive." They also presented evidence for and against the fibrogenicity and tumorigenicity of short fibers, including those which were identifiable only under the electron microscope, and concluded "that there can be no firm conclusions from the present evidence."[8] Some investigators believe, however, that the smaller asbestos particles are more significant in penetrating cells and causing damage.[9] Although we did not confirm the presence of asbestos fibers too small to be identified at 450×, the hands of the experimenter in our ingestion experiments probably were contaminated with these smaller particles in addition to the significant numbers of fibers longer than 5 μm which were counted.

The present study shows that gradual soiling of gloves, particularly with sticky material such as microbiological media, reduces the extent of fiber emission, apparently by a coating action. On the other hand, repeated usage of the gloves damages the surface integrity and promotes release of fibers. It was surprising to observe the ragged condition of some of the gloves being used by workers; an example is shown in Figure 2. Such gloves, which were not included in our measurements, would be expected to emit more fibers than the well-worn gloves studied.

With the exception of one workplace sample, the TWA concentrations of the breathing zone samples in the biology preparation room and actual workplaces did not exceed the current OSHA standard of two asbestos fibers/cm^3. However, the NIOSH-OSHA Asbestos Work Group has recommended lowering the TWAC limit for asbestos fibers to 0.1 fiber/cm^3.[10] All mean TWAC values for breathing zone samples in the biology preparation room, except that for brand-new gloves with normal workload, exceeded this lower level, as did five of the seven breathing zone samples from the workplaces.

After surveying the literature on the relationship between industrial exposure to asbestos and later development of bronchial, lung, and digestive tract cancers, a reviewer concluded that the data do not provide much evidence for a threshold or the existence of a clearly "safe" level of exposure.[11] Thus, any unnecessary exposure to asbestos should be discontinued. The NIOSH-OSHA Asbestos Work Group stated that even when exposure is controlled to levels below the proposed new standard, "there is no scientific basis for concluding that all asbestos-related cancers would be prevented," and recommended the substitution of less hazardous materials where they exist.[10] Fortunately, various substitutes for asbestos gloves are available.[12] Gloves made of Zetex, a silica-based product, are advertised to withstand continuous temperatures up to 593 °C and higher temperatures for short durations; those made of Nomex, a heat-resistant nylon, are claimed to withstand sustained exposure at 250 °C and short exposure to thermal shock at 350 °C. A silicone-rubber hand grip can be used for removing trays or small items from autoclaves and ovens. Considering the results of the present study, we strongly urge the adoption of these or similar substitutes for asbestos gloves.

acknowledgement

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