Applied Occupational and Environmental Hygiene

ISSN: 1047-322X (Print) 1521-0898 (Online) Journal homepage: https://www.tandfonline.com/loi/uaoh20

A Comparative Study of the National Institute for Occupational Safety and Health 7400 "A" and "B" Counting Rules Using Refractory Ceramic Fibers

Teresa M. Buchta , Carol H. Rice , James E. Lockey , Grace K. Lemasters & Peter S. Gartside

To cite this article: Teresa M. Buchta , Carol H. Rice , James E. Lockey , Grace K. Lemasters & Peter S. Gartside (1998) A Comparative Study of the National Institute for Occupational Safety and Health 7400 "A" and "B" Counting Rules Using Refractory Ceramic Fibers, Applied Occupational and Environmental Hygiene, 13:1, 58-61, DOI: 10.1080/1047322X.1998.10389547

To link to this article: https://doi.org/10.1080/1047322X.1998.10389547

A Comparative Study of the National Institute for Occupational Safety and Health 7400 "A" and "B" Counting Rules Using Refractory Ceramic Fibers

Teresa M. Buchta,[A] *Carol H. Rice,*[B] *James E. Lockey,*[B] *Grace K. Lemasters,*[B] *and Peter S. Gartside*[B]

[A]Geotechnical Services, Inc., Omaha, Nebraska; [B]University of Cincinnati College of Medicine, Cincinnati, Ohio 45220

During the course of a study to characterize exposure to refractory ceramic fibers (RCFs), the method of analyzing the concentration of airborne fibers changed from the "A" rules originally specified in National Institute for Occupational Safety and Health Method 7400 to the "B" rules. Differences in the two rules include a diameter specification, the value for the aspect ratio to define a fiber, whether to count entire fibers or ends of fibers, and how to count bundles of fibers. To determine if the fiber density on the filter differed between the two methods for samples collected in RCF manufacturing or associated production, a comparative study was undertaken by applying both counting rules in the evaluation of 150 slides. The analyst was blind to previous results throughout the study. The results from applying the "A" and "B" counting rules to determine fiber density were highly correlated ($r = 0.98$). After log transformation, a paired t-test indicated no difference in fiber density between the two counting rules ($t = 0.299$, $df = 143$, $p = 0.38$). In addition, four slides were evaluated ten times each to evaluate any possible difference in intracounter variability. The intracounter variability was similar in magnitude for each of the counting rules. The findings indicate that it is possible to combine the results from the "A" and "B" counting rules when conducting a long-term exposure assessment of RCF manufacturing operations. In other situations of RCF exposure where both counting rules are used in determining exposure, the investigator is urged to evaluate whether the analytical method affects the calculated concentration. BUCHTA, T.M.; RICE, C.H.; LOCKEY, J.E.; LEMASTERS, G.K.; GARTSIDE, P.S.: A COMPARATIVE STUDY OF THE NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH 7400 "A" AND "B" COUNTING RULES USING REFRACTORY CERAMIC FIBERS. APPL. OCCUP. ENVIRON. HYG. 13(1):58–61; 1998. © 1998 AIH.

Man-made vitreous fibers, including refractory ceramic fibers (RCFs), comprise a wide range of amorphous synthetic fibers which can withstand temperatures above 1100°C.[1] RCF is typically made from kaolin, alumina, silica, and zirconium. Most of the ceramic fibers are composed of a 50/50 mixture of alumina and silica.[2] These fibers are thermally nonconductive, have high tensile strength, and resist physical degradation at high temperatures.[1] Typically, ceramic fibers represent a wide range of diameters and lengths, including diameters in the respirable range.[3] Therefore, a portion of the ceramic fibers released into the work environment may present a potential for inhalation.

An industry-wide study in facilities where RCF is manufactured has been conducted to evaluate workplace exposures according to a standardized protocol. Although the individual production processes vary somewhat from plant to plant, the initial step for all RCF products is the formation of the ceramic fiber. In the batch house or storage area the raw materials are blended; the batch mix is then transferred either manually or mechanically to the high temperature furnace where the mix is melted. This molten material flows from the furnace and is fiberized by either a spinning or a blowing process. Approximately 50 percent of the mix is converted to a fibrous form; the remainder is nonfibrous shot.[2,4].

Fibers may be bagged, baled, or used to form blankets, felts, boards, yarn/textiles, or other specialty products. To form blankets, fibers are introduced into a large settling chamber containing aerosolized lubricating oil. Fibers settle onto a moving conveyor and are passed through opposing needle boards which interlock the fibers. The oil is subsequently burned off, and the blanket is trimmed and packaged. Blanket materials may be formed into folded or specially shaped module products. Felts and boards are produced from a slurry containing RCF; the water is removed and the resulting product is cut and finished for shipping.

Beginning in 1987, a standardized study protocol was implemented for the collection and analysis of samples to characterize exposure to airborne fibers. According to the study protocol, samples were collected according to National Institute for Occupational Safety and Health (NIOSH) Method 7400. Originally the protocol included the use of the "A" counting rules in the analysis of air samples to determine fiber concentration. This decision was based on the Occupational Safety and Health Administration requirement that airborne asbestos samples be analyzed using the "A" rules, even though there is no such specification for RCF. After approximately 2 years of sample collection, the protocol was modified and the "B" counting rules were introduced for the analysis of man-made vitreous fiber samples. Thus, over time, data available for exposure assessment resulted from two different analytical approaches.

The "B" counting rules were developed as a result of research conducted by the Institute of Occupational Medicine under the auspices of the Commission of the European Com-

TABLE 1. Comparison of the "A" and "B" Counting Rules

A Rules	B Rules
1. Count only fibers ≥5 μm in length.	1. Count only ends of fibers ≥5 μm in length and ≤3 μm in diameter.
2. Count only fibers with a length-to-width ratio ≥3:1.	2. Count only fibers with a length-to-width ratio ≥5:1.
3. For fibers that cross the boundary of the graticule field area and meet the criteria of rules 1 and 2: a. Count any fiber with only one end lying within the graticule area as one half. b. Do not count any fiber that crosses the graticule boundary more than once.	3. For fibers that cross the boundary of the graticule field area and meet the criteria of rules 1 and 2: a. Count each fiber end that lies within the graticule area as one end. Add split ends to the count if the split meets the criteria of rules 1 and 2. b. Count visible ends when the fiber appears to be attached to another particle, regardless of the size of the particle. Count the end of a fiber obscured by another particle if the particle covering the fiber is less than 3 μm in diameter.
4. Count bundles of fibers as one fiber unless the individual fibers can be identified, observing both ends and meeting the criteria of rules 1 and 2.	4. Count free ends of the fibers from large clumps and bundles up to a maximum of ten ends, provided that each segment meets the criteria of rules 1 and 2.
5. Count enough graticule fields to yield 100 fibers. Count a minimum of 20 fields. Stop at 100 graticule fields regardless of the count.	5. Count enough graticule fields to yield 200 ends. Count a minimum of 20 fields. Stop at 100 graticule fields regardless of the count. Divide the total end count by 2.

munities. The "A" counting rules were formerly known as the NIOSH P&CAM 239; the "B" counting rules were adopted from the Central Reference Scheme rules developed by the United Kingdom Health and Safety Executive.[5] The "A" rules define a fiber as any visible particle having a length greater than 5 μm and an aspect ratio of 3:1 or greater. The "B" counting rules require a fiber to have a length greater than 5 μm, a minimum 5:1 aspect ratio, and an upper diameter limited to 3 μm.[6] The two methods are summarized in Table 1.

Comparison of the results using both the 5:1 and 3:1 aspect ratio criteria for asbestos samples indicated a 12 percent reduction in the counted value as a result of using the 5:1 aspect ratio, although both counting criteria produced similar mean concentrations.[7,8] No similar comparison has been published for air samples of RCFs. The work reported here was undertaken to better understand any differences between RCF concentrations resulting from the two methods of analysis.

Materials and Methods

Industrial hygiene sampling was performed using NIOSH Method 7400 at seven facilities across the country. Sample air was drawn through an open-faced cassette containing a mixed cellulose ester membrane (0.8-μm pore size, 25-mm diameter) using a calibrated sampling pump. The air samples were collected in the personal breathing zones of workers at a nominal flow rate of 2 L/min to produce a fiber density of approximately 100 to 1300 fibers/mm^2. Sample preparation was performed at a commercial laboratory. A quarter wedge of the membrane was cut and mounted, using an acetone–triacetin preparation technique, onto a clean glass microscope slide.

Sample analysis was performed at the University of Cincinnati using the following equipment: a Nikon microscope 40× phase contrast achromatic objective with a 0.65 numerical aperture, a Green filter, a Walton-Beckett graticule, an HSE/NPL Mark II phase contrast test slide, an ocular phase-ring centering telescope, and a stage micrometer (0.01-mm divisions). The microscope was calibrated prior to sample analysis, including adjustment of the field iris and the light source to achieve Kohler illumination and alignment of the phase rings using the ocular telescope. The phase-shift detection limit of the microscope was also checked to verify the proper resolution using the HSE/NPL phase contrast test slide. The graticule field area was measured weekly using the stage micrometer.[6]

Fibers were counted by viewing a number of random fields, starting at the tip and progressively moving along a radial line to the outer edge of the filter wedge. The range of the focal planes was continuously scanned to detect any fibers embedded in the filter.

150 sample filters were first analyzed using the "A" counting rules, and then using the "B" counting rules. The fiber density of each sample was calculated by dividing the number of fibers counted on the filter by the measured field area. A paired *t*-test was performed to detect any differences in the results obtained from the two methods.[9].

Four slides, selected because of varying fiber density, were counted ten times each using both methods of analysis. The slides were evaluated in random order and the analyst was blind to original fiber density. The fiber density of each sample was calculated and the variance in the fiber counts for each slide was determined for both methods. An F-test was then performed to determine if there was a statistical difference in the variances obtained from the two methods.[9] For quality control, 10 percent of the 150 slides were recounted.

Results

The data generated from the analysis of the 150 samples are shown in Figure 1, with the fiber densities obtained from the "A" counting rules as the abscissa and the fiber densities obtained from the "B" counting rules on the ordinate. The correlation coefficient (r) is 0.98; with the outlier removed, r = 0.97.

A frequency distribution of the data sets generated by the "A" and "B" counting rules indicated that the fiber density values were lognormally distributed. To calculate the paired

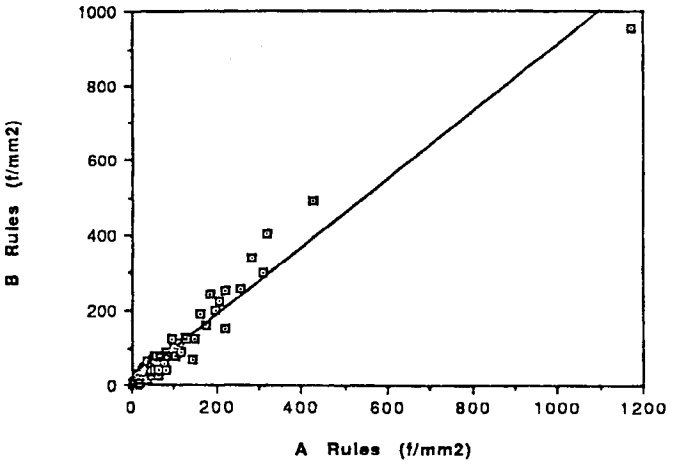

FIGURE 1. Plot of the fiber densities obtained from the "A" and "B" counting rules analysis of 150 samples. The regression line shown is given by y = 4.7 + 0.9x.

t-test, a natural log transformation of the data was performed. After this transformation, the data sets were assessed for normality using the Shapiro–Wilk W statistic. The results of 0.98 and 0.98 indicated that the data sets for the "A" and "B" rules, respectively, were more normally distributed after the transformation.

A paired *t*-test was performed on the set of 150 transformed counts to determine if there was a statistical difference in the results obtained from the two counting techniques. The result of the paired *t*-test was a test statistic of 0.299 with 143 degrees of freedom, p = 0.38, indicating no difference in fiber density between the two counting rules.

The data generated from the analysis of the four slides which were counted ten times each using both methods are shown in Table 2. A natural log transformation was performed on these data and an F-test statistic was calculated to determine if there was a statistical difference in the variance obtained from the two counting rules. The F statistic (and p value) was 1.73 (0.21), 2.43 (0.10), 2.26 (0.12), and 3.06 (0.06), respectively. Although the standard deviation was slightly less for the "B" rules in three of the four samples, the results from the F-test for each of the individual slides indicated no statistically significant difference between the variance of the two methods ($p > 0.05$), that is, the intracounter variation was similar in magnitude for the slides counted with the "A" and "B" rules.

TABLE 2. Mean, Standard Deviation, and Coefficient of Variation of Fiber Densities (Fibers per Square Millimeter) for Four Slides Evaluated for Intracounter Variability in the "A" and "B" Counting Rules

Sample Number	Mean		Standard Deviation		Coefficient of Variation	
	A	B	A	B	A	B
1	35.4	35.2	4.9	6.7	13.9	19.1
2	92.2	77.6	16.8	8.8	18.2	11.4
3	13.4	13.0	5.4	4.3	40.1	33.2
4	184.3	186.0	25.4	14.2	13.8	7.6

A = "A" counting rules; B = "B" counting rules.

Summary and Conclusions

The purpose of this research was to compare the NIOSH Method 7400 "A" and "B" counting rules used for estimating worker exposure to RCF. Although the two methods differ according to the definition of a fiber, the data demonstrate no significant difference in the relative counting levels obtained. Additionally, the data from repeated analysis of samples provided evidence that both counting techniques had similar magnitudes of intracounter variation. Therefore, the findings indicate that it would be possible to combine the results from these two methods when conducting a long-term exposure assessment evaluation of RCF manufacturing operations. Had data been available regarding the size of airborne fibers at these facilities, it would have been possible to predict whether or not use of the two rules would have resulted in different results; in the absence of such data, the approach reported was undertaken.

It is suggested that in other settings, researchers should conduct a similar evaluation prior to merging samples analyzed by different rules, since differences in the "A" and "B" rule results have been reported during installation and removal of ceramic fibers.[10] Should differences be found, archived slides may be available which can be analyzed by the current method. Recounting has been shown to provide valid estimates of exposure if the quality of the slide preparation has been maintained.[11] Alternatively, recently collected filter wedges may be counted using both the "A" and "B" rules and the results compared to determine if a correction factor can be identified; if so, the concentration reported using the "A" rules may be corrected to obtain an estimate of the concentration which would have resulted had the "B" rules been used to evaluate all samples.

Acknowledgments

This project was supported in part by a contract from the Thermal Insulation Manufacturers' Association. Ms. Buchta received funding from grant OH 07091-11 and -12 from the National Institute for Occupational Safety and Health of the Centers for Disease Control and Prevention. Preliminary results were reported at the American Industrial Hygiene Conference, Orlando, Florida, May 1990. The assistance of Linda Alerding in preparation of this manuscript is gratefully acknowledged.

References

1. Grayson, M.: Refractory Fibers. In: Kirk and Othmer Encyclopedia of Chemical Technology, 3rd ed., Vol. 20. John Wiley and Sons, New York (1982).
2. World Health Organization: Man-made Mineral Fibers and Radon. In: International Agency for Research on Cancer Monographs on Evaluation of Carcinogenic Risks to Humans, Vol. 43. IARC, UK (1988).
3. Rood, A.P.: Size Distribution of Airborne Ceramic Fibers as Determined by Transmission Electron Microscopy. Ann. Occup. Hyg. 32:237–240 (1988).
4. Thermal Insulation Manufacturers' Association: Health and Safety Aspects of Man-Made Vitreous Fibers. TIMA, Inc., Stanford, CT (1990).
5. Baron, P.: Asbestos Analysis-NIOSH Method 7400. Appl. Ind. Hyg. 2:R8–10 (1987).
6. National Institute for Occupational Safety and Health: NIOSH

Method 7400, Revision #3. In: NIOSH Manual of Analytical Methods, 3rd ed. NIOSH, Cincinnati, OH (1989).
7. Cowie, A.J.; Crawford, N.P.: A Comparison of the Effects of Different Counting Rules and Aspect Ratios on the Level and Reproducibility of Asbestos Fibre Counts. Part 1: Effects on Level. Report No. TM/82/23. Institute of Occupational Medicine, Edinburgh, Scotland (1992).
8. Crawford, N.P.; Thorpe, H.L.; Alexander, W.: Comparison of the Effects of Different Counting Rules and Aspect Ratios on the Level and Reproducibility. Report No. TM/82/24. Institute of Occupational Medicine, Edinburgh, Scotland (1992).
9. Rosner, B.: Fundamentals of Biostatistics, 2nd ed. Duxbury Press, Boston, MA (1986).
10. Satrun, E.A.: Personal communication to C. Rice (1993).
11. Machol, K.E.; Rice, C.; Lockey, J.; et al.: A Study of Fiber Migration in Prepared Slides for the Refractory Ceramic Fiber Industry. Presented at the American Industrial Hygiene Conference, Orlando, FL (1990).