Arh hig rada toksikol 1992;43:359–364

Original Scientific Paper
UDC 613.633:549.6:53.083.1

INTERCONVERTIBILITY OF ASBESTOS FIBRE COUNT CONCENTRATIONS RECORDED BY THREE MOST FREQUENT METHODS

F. Valić and M. Cigula

»Andrija Štampar« School of Public Health, Medical Faculty, University of Zagreb, Zagreb, Croatia

Received July 25, 1992.

Simultaneous airborne chrysotile asbestos fibre samples were collected with three types of instruments, namely, the konimeter, the thermal precipitator and the membrane filter, in four asbestos plants (textile manufacturing, asbestos cement production, mining, milling). Linear regression analyses were performed of the membrane filter on the konimeter and thermal precipitator count concentrations, respectively. Sampling was performed at 24–35 locations in each of the processes studied. In order to linearize the relationships and to stabilize the sample variances the data were transformed using the transformation $\ln(x+1)$ for both the predictor and the response variables. Eight linear regression equations were developed. The slope coefficients of regressions differed significantly ($P<0.05$ or <0.01) between all the asbestos processes except for the differences of coefficients in mining and milling ($P>0.05$). It is concluded that no single conversion factor can be used to reliably convert the konimeter or thermal precipitator to membrane filter asbestos fibre concentrations; a separate conversion factor must be derived for each technological process. In this case the confidence limits of estimates are acceptable for practical occupational hygiene purposes.

Key terms: asbestos count conversions, asbestos determination, asbestos fibres.

Asbestos Convention No. 162 (1) and Asbestos Recommendation No. 172 (2), adopted at the General Conference of International Labour Organization in 1986, stipulate that for the monitoring of exposure to asbestos fibres methods are to be used which have been approved by a competent national authority. The main methods applied for the determination of airborne asbestos fibres use the midget impinger, the thermal precipitator, the konimeter or the membrane filter. Several authors have demonstrated significant differences in the results obtained by different methods (3–9). On the basis of the recommendations of a number of international organizations (10–14), *Valić and Skurić* (15) suggested phase contrast optical microscopy of asbestos fibres sampled on membrane filters as the standard method for the countries of former Yugoslavia. They emphasized, however, that konimetry and thermal precipitation were used more frequently than the membrane filtration method, as had been the case in many other countries in the past. The question remained open of whether it was possible to convert the results obtained by the former methods to those which would be obtained by the standard membrane filtration method. Two related papers were presented at the First Meeting on Problems of Asbestosis, held in Dubrovnik in 1985. While one presented lower asbestos concentrations by the konimeter than by the thermal precipitator (16), the second reported higher concentrations obtained by the konimeter (17).

Several papers have been published on the interconvertibility of airborne asbestos fibre concentrations determined by different methods. *Roach* (4) and *Walton* (5) have shown large differences in concentrations when using different methods. *Du Toit* and *Gilfillan* (7, 8) and *Du Toit and co-workers* (9) studied the comparability of results obtained by konimetry, thermal precipitation and membrane filtration in asbestos mines and mills. The dispersion of results was very large but, nevertheless, they attempted to develop equations that would allow the conversion of results determined by one to those that would be obtained by another method. *Peruničić and Jablanov* (18) showed a high correlation between asbestos count concentrations by the konimeter and the thermal precipitator in asbestos textile production, but not in the production of friction material.

The purpose of our paper is to show that the use of a single conversion factor could lead to prohibitively large errors of estimate if the factor is obtained across asbestos exploitation and processing without differentiating technological processes. It is to our knowledge the only report hitherto on the comparison of simultaneous determinations of airborne chrysotile asbestos fibre count concentrations by three most frequently applied methods in four technological processes (asbestos mining and milling, asbestos cement and textile production).

METHODS

Instruments. Three types of instruments were used: konimeter, thermal precipitator and membrane filter sampler. Carl Zeiss konimeters, model I, were used with 5 cm^3 air samples impinging onto their circular plate coated with an adhesive. Water aspirated Casella thermal precipitators were used with an airflow of 7 cm^3/minute. Samples were counted under dark field illumination at a magnification 200x (konimeter) or 250x (thermal precipitator). Millipore field monitors were used with membrane filter dia. 37 mm, 0.8 μm pore size; the flow rate was about 1.8 L/min. The mounted filters were evaluated by phase contrast microscopy (15) at a magnification 400x.

Only respirable fibres were counted (diameter $\leq 3\,\mu$m, length $\geq 5\,\mu$m, aspect ratio $\geq$3:1).

Sampling strategy. Simultaneous samples were taken at four different operations: open pit mining, asbestos milling, asbestos cement production, and asbestos textile production. One thermal precipitator sample was taken through 30–60 minutes depending on the dust concentration. Simultaneously, konimeter samples were taken every two minutes. In general, the count concentrations of one four-hour membrane filter sample, and simultaneously collected four thermal precipitator and 120 konimeter samples, were taken as representative of one sampling location. At locations of high fibre concentrations the duration of sampling was correspondingly reduced. Sampling was performed at 24–35 locations in each of the processes studied.

Statistics. Linear regression analyses were performed on fibre concentrations (f/cm^3) and after logarithmic transformations of concentrations [ln(f/cm^3 + 1)]. The 95% confidence limits were calculated and the significances of differences between slope coefficients were tested. The calculations were carried out by means of the MICROSTAT computer programme.

RESULTS

When plotting the fibre concentrations of sample pairs on a linear scale, a cluster of points near the origin and increasing scatter of points at higher fibre counts were found in the majority of cases. That indicated an increasing variance with fibre count. In addition, the relationships of concentrations were not linear. The results required some transformation to linearize the relationship and to stabilize the sample variance over the entire range of fibre concentrations. *Du Toit and Gilfillan* (9) tried three transformations, namely ln(x+1), ln[ln(x+1)+1] and log [log (x+1)+1]. As the first one is the simplest to apply and was not found by them to be inferior to the other transformations, we used it throughout our analysis, so that all our regression equations are based on the data transformed in this way.

In the Table regression parameters are presented for the conversion of konimeter (K) and thermal precipitator (TP) asbestos concentrations to membrane filter (MF) concentrations in four processes. The results of t-testing of the differences of the slope coefficients are also presented, as well as the respective correlation coefficients.

High correlation coefficients between K and TP, respectively, and MF asbestos concentrations were found both in asbestos textile and cement production. They were considerably lower in mining. Correlation coefficients between K and TP were similar to those

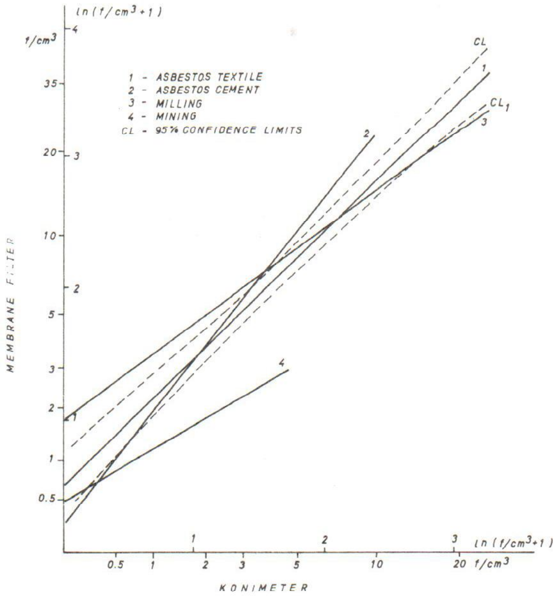

Figure *Fibre concentrations by konimeter versus fibre concentrations by membrane filter*

Table

Conversion from konimeter (K) or thermal precipitator (TP) to membrane filter (MF) asbestos fibre concentrations

Process	MF = a +bK				MF = a + bTP			
	Conversion equation	Intercept	Slope coefficient	Correlation coefficient	Conversion equation	Intercept	Slope coefficient	Correlation coefficient
Textile	1	0.5121	0.9531	0.9310	5	0.4187	0.9098	0.9582
Cement	2	0.2132	1.2308	0.8838	6	0.1581	1.0622	0.9225
Milling	3	1.0006	0.7198	0.8384	7	1.0343	0.6477	0.7725
Mining	4	0.4065	0.5699	0.5395	8	0.3987	0.5443	0.4322

Significance of difference between slope coefficients

Slopes	1–2	1–3	1–4	2–3	2–4	3–4	5–6	5–7	5–8	6–7	6–8	7–8
t	–2.67	2.62	2.14	4.48	3.34	0.85	–2.11	3.12	2.16	4.17	2.81	0.49
P	<0.01	<0.05	<0.05	<0.01	<0.01	>0.05	<0.05	<0.01	<0.05	<0.01	<0.01	>0.05

K, TP, MF: $\ln(f/cm^3 + 1)$

shown in the Table but are not presented since the main purpose of the paper is to analyse the possibility of conversion of K and TP concentrations, respectively, in to the MF concentrations. The differences of all the slope coefficients tested were statistically significant ($P<0.05$ or <0.01) except for the differences of coefficients in mining and milling, both in K versus MF and TP versus MF ($P>0.05$).

Relationships between konimeter and membrane filter asbestos concentrations in the four processes are presented in the Figure. For illustration purpose, 95% confidence limits of the relationship in the textile production are also presented. The Figure clearly shows that the only slopes that are not significantly different ($P>0.05$) are those in mining and milling. The comparatively narrow confidence limits give an indication that the conversion from K to MF results is possible within the same technological process. The same holds for the conversion from TP to MF results which is not presented in the Figure.

DISCUSSION

Our results do not support the assumption that a single conversion factor across asbestos industry can be used to convert the results recorded by the konimeter or the thermal precipitator to membrane filter equivalents. The results presented in the Table show that the slope coefficients of regression of MF count concentrations on K and TP concentrations, respectively, differ significantly between almost all the asbestos processes studied. The only exceptions are differences in slopes in mining and milling in both the regression of K on MF and TP on MF count concentrations. In other words, no single conversion factor can be used; a separate conversion factor must be derived for each technological process.

The 95% confidence limits, calculated for each regression line, show that the conversion error is within acceptable limits if the conversion factor is calculated for each technological process separately. As examples, it can be calculated from the Figure that 1 f/cm^3 determined by the konimeter would correspond to 1.8–2.7 f/cm^3 by the membrane filter (variation $\pm 21\%$), and 3 f/cm^3 by konimeter to 4.6–5.9 f/cm^3 by membrane filter (variation $\pm 12\%$), which would be acceptable for practical occupational hygiene purposes.

We wish to emphasize that our conclusions are based on comparatively small numbers of sample pairs. In order to clarify the problem in a more definitive manner additional simultaneous samples will have to be collected which would be representative of the asbestos industry.

REFERENCES

1. *International Labour Organization.* Asbestos Convention. ILO Convention No. 162. Geneva, 1986.
2. *International Labour Organization.* Asbestos Recommendation. ILO Recommendation NO. 172. Geneva, 1986.
3. *Ayer HE, Lynch JR, Fanney JH.* A comparison of impinger and membrane filter technique for evaluating air samples in asbestos plants. Ann NY Acad Sci 1965;132:274–87.
4. *Roach SA.* Measurement of asbestos dust by instruments measuring different parameters. Ann NY Acad Sci 1965;132:306–15.
5. *Walton WH.* The nature, hazards and assessment of occupational exposure to airborne asbestos dust: A review. Ann Occup Hyg 1982;25:117–247.
6. *Du Toit RSJ.* Review of early results of comparative tests with the konimeter and thermal precipitator in asbestos mines. Ann Occup Hyg 1977;20:279–81.
7. *Du Toit RSJ, Gilfillan TC.* Simultaneous airborne dust samples with konimeter, thermal precipitator and dosimeter in asbestos mines. Ann Occup Hyg 1977;20:333–40.

8. *Du Toit RSJ, Gilfillan TC.* Conversion of asbestos fibre concentrations recorded by means of the konimeter and the thermal precipitator to that expected by means of the membrane filter method. Ann Occup Hyg 1979;22:67–83.
9. *Du Toit RSJ, Isserow LW, Gilfillan TC, Robock K, Teichert U.* Relationship between simultaneous airborne dust samples taken with five types of instruments at South African asbestos mines and mills. Ann Occup Hyg 1983;27:373–87.
10. *Asbestos Research Council.* The measurement of airborne asbestos dust by the membrane filter method. ARC Technical note No. 1. Rochedale: Asbestos Research Council, 1971.
11. *Asbestos International Association.* Reference method for the determination of airborne asbestos fibre concentrations at work places by light microscopy (membrane filter method). AIA Health and Safety Publications RTM No. 1. London: Asbestos International Association, 1982.
12. *International Labour Organization.* Safety in the use of asbestos. ILO Code of Practice. Geneva: International Labour Office, 1984.
13. *European Economic Communities.* Council directive on the protection of workers from the risks related to exposure to asbestos at work. Bruxelles: EEC, 1983.
14. *International Standards Organization.* Proposed analytical method for determination of asbestos fibres in air. Geneva: International Standards Organization, 1984.
15. *Valić F, Skurić Z.* Metodologija ocjenjivanja profesionalne izloženosti vlaknima azbesta. Arh hig rada toksikol 1988;39:169–81.
16. *Jablanov Lj, Peruničić B.* Simultano mjerenje zaprašenosti sa više metoda u fabrici azbestno-tekstilnih proizvoda. I radni sastanak o problemima azbestoze u Jugoslaviji, Dubrovnik. Knjiga sažetaka, 1985;29–30.
17. *Kuljiš V.* Brza detekcija visokih koncentracija azbestne prašine konimetrom – metoda mjerodavna za ocjenu ugroženosti radnika. I radni sastanak o problemima azbestoze u Jugoslaviji, Dubrovnik. Knjiga sažetaka, 1985;30.
18. *Peruničić B. Jablanov Lj.* Zaprašenost u fabrici za preradu hrizotilnog azbesta: Rezultati simultanog mjerenja sa više metoda. Arh hig rada toksikol 1987;38:323–30.

Sažetak

MOGUĆNOST MEĐUSOBNE PRETVORBE BROJČANIH KONCENTRACIJA VLAKANA AZBESTA ODREĐENIH POMOĆU TRI NAJČEŠĆE UPOTREBLJAVANE METODE

Uzorci vlakana krizotil azbesta istodobno su skupljani pomoću konimetra, termalnog precipitatora i membranskog filtra u proizvodnji azbest tekstila, proizvodnji azbest cementa, rudniku i separaciji azbesta. Izvedene su analize linearne regresije koncentracija dobivenih membranskim filtrom u ovisnosti o koncentracijama dobivenim konimetrom odnosno termalnim precipitatorom. Uzorci su skupljeni na 24–35 lokacija u svakom procesu. Da bi se linearizirali odnosi i stabilizirale varijacije uzoraka, nezavisne i zavisne varijable logaritamski su transformirane [ln(x+1)]. Analizirano je osam linearnih regresija. Koeficijenti smjera regresija međusobno su se značajno razlikovali ($P<0{,}05$ ili $<0{,}01$) u svim procesima osim u separaciji i rudniku ($P>0{,}05$). Zaključuje se da se ne može upotrebljavati isti faktor za pretvorbu koncentracija azbesta određenih konimetrom ili termalnim precipitatorom u koncentraciju koja bi bila određena membranskom filtracijom; za svaki tehnološki proces potreban je poseban faktor pretvorbe. U takvom slučaju su granice pouzdanosti ocjenjivanja prihvatljive za praktičku terensku primjenu.

Škola narodnog zdravlja »Andrija Štampar«, Medicinski fakultet Sveučilišta u Zagrebu, Zagreb, Hrvatska

Ključne riječi: određivanje azbesta, pretvorba brojčanih koncentracija azbesta, vlakna azbesta.