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INTER-LABORATORY COMPARISONS OF THE COUNTING OF ASBESTOS FIBRES SAMPLED ON MEMBRANE FILTERS

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Abstract—Two series of exchanges of slide-mounted asbestos samples have been conducted between British laboratories, to determine the degree of agreement between different laboratories counting the same slides, the effectiveness of written compared with personal instruction, and the reasons for disagreements. It was found that disagreements between laboratories that were isolated or new to fibre counting were large, but were reduced by direct personal consultation. The main causes of these differences were uncertainties in the counting of irregular fibres and fibre masses, misalignment of the microscope phase rings, and failure to scan the full depth of focus in which fibres were present. Results of an exchange between several experienced laboratories showed that counting over the whole field of view of the microscope consistently returned substantially lower count densities than when only the central graticule area was evaluated. All disagreements were more serious for UICC asbestos samples than for samples collected from factory air. It is concluded that there is a need for closer definition and standardisation of counting procedures.

INTRODUCTION

THE MOST widely-used method of measuring airborne asbestos fibre is to sample on a membrane filter and then to count the fibres by phase contrast microscopy. This method was developed by the Asbestosis Research Council (ARC) (HOLMES, 1965) and forms the basis of the BOHS *Hygiene Standards for Chrysotile Asbestos Dust* (BOHS COMMITTEE ON HYGIENE STANDARDS, 1968). The counting procedure is described in an ARC publication (ARC, 1971) and in the BOHS standard.

When the Institute of Occupational Medicine began research on the asbestos hazard for the ARC, the staff had considerable experience of counting coalmine dusts but none of counting asbestos fibres. This previous experience had shown the difficulties of ensuring closely comparable results between counters in different laboratories and the need for frequent interchange of check samples (HOLDSWORTH *et al.*, 1954). Two exchanges of asbestos samples mounted on slides were therefore planned.

The aim of the first exercise was to examine the variability of asbestos counts between inexperienced laboratories starting to count asbestos on the basis of the published descriptions. It was hoped that the information gained would indicate any need for further clarification of the instructions, and also show what improvement would follow personal tuition.

The second exchange was planned to examine the level of agreement between experienced units regularly engaged in counting asbestos slides, and, if possible, the causes of any differences which occurred. All the laboratories involved had previously maintained regular contact.

The participating laboratories were widely dispersed throughout the country, and the slides were transmitted by post.

TRIAL 1: ASBESTOS FIBRE COUNTING BY INEXPERIENCED LABORATORIES

Procedure

The laboratories involved were:

(a) Four laboratories (A,B,C,D) experienced in counting non-fibrous mineral dusts, but not asbestos; these were asked to count according to the instructions given in Technical Note 1 (ARC, 1971).

(b) A laboratory (E) experienced with asbestos, but with no regular contact with other counters.

(c) Two experienced laboratories (F, G) maintaining regular slide exchanges and comparisons, whose results were taken as the standards.

Eleven slides were used in the trial. All were routine samples from three of the participating laboratories prepared according to the method described by the ARC (1971). The sample densities ranged from 2×10^3 to 112×10^3 fibres/cm^2; the materials were chrysotile (UICC standard reference samples (TIMBRELL and RENDALL, 1971) and from an asbestos textile factory), amosite (from an asbestos cement factory), and crocidolite (from the removal of lagging). It was intended that all the slides would be counted by each participant, but this was not possible owing to breakages and the limited amount of time available at some of the laboratories; all the slides were evaluated by at least one of the 'standard' laboratories. The counters could not identify individual slides; the exchange between laboratories was randomised. After the initial circulation of slides, some of the participants from the new laboratories met at one centre and counted slides in collaboration with a more experienced counter. The reasons for any differences were examined and noted. Several slides were then recirculated in order to determine any changes in counting level.

Results

The results are summarised in Table 1. It can be seen that the counts by the inexperienced laboratories before contact were considerably lower than the standard, being about half the standard for the 'factory' samples and one quarter for UICC chrysotile. The agreement with the standard counters greatly improved after personal tuition (see Table 1). Occasionally the new observers, after tuition, tended to over compensate and get exceedingly high counts. It is also clear that the consistency between the counters was worse for the UICC chrysotile than for the other types of asbestos, presumably because of its smaller fibre diameter and irregular shape.

It was found that the counts obtained by the experienced laboratory which had previously remained without contact with outside establishments (E, in Table 1) were as far from the standard values as the counts by the novices.

Problems encountered by the new readers

Three main difficulties encountered by the new readers were: (i) the problem of deciding what to count as one fibre ; (ii) the need to scan through a considerable depth of focus; and (iii) the use of a phase contrast microscope.

The problem of defining a fibre which is to be counted arises because of the presence of abnormal and split fibres, fibres attached to other particles, and fibre conglomerates.

TABLE 1. RESULTS OF SLIDE EXCHANGE BETWEEN INEXPERIENCED LABORATORIES

Slide number and type	Standard laboratories (10^3 fibres/cm^2)			Inexperienced laboratories: Before contact (Ratio count/standard)					Inexperienced laboratories: After contact (Ratio count/standard)					Experienced laboratory but no outside contact
	F	G	Mean	A	B	C	D	Mean	A	B	C	D	Mean	E
1. Factory chrysotile	4·75	5	4·9	0·21	0·66		0·86	0·58	1·0			0·98	0·99	
2. Factory chrysotile	2·86	2·4	2·63	0·7	0·54		0·5	0·58	1·95			1·0	1·5	
3. Crocidolite	34	34	34			0·56	0·7	0·63			0·9	0·96	0·93	0·23
4. Crocidolite	9·2	8·0	8·6		0·38	0·24	0·6	0·41			0·95	0·97	0·96	0·19
5. Crocidolite		3	3			0·4	0·6	0·5			0·92	0·84	0·88	0·23
6. Amosite	8·1	8·7	8·4		0·55		0·65	0·6				0·91	0·91	
Mean ratio				0·46	0·53	0·4	0·65	0·55	1·4		0·92	0·94	1·03	0·22
7. UICC chrysotile	7	13	10	0·35	0·1	0·4		0·28	0·64			0·8	0·72	
8. UICC chrysotile		11·2	11·2	0·25	0·1	0·27		0·2	0·65		0·7		0·68	
9. UICC chrysotile	11	5	8	0·33	0·23		0·38	0·31	0·43			0·9	0·66	
10. UICC chrysotile	124	85	105		0·07	0·02	0·3	0·13			0·08	0·85	0·48	
11. UICC chrysotile	72	80	76		0·13		0·53	0·33	0·6			1·03	0·85	
Mean ratio				0·31	0·13	0·15	0·4	0·25	0·6		0·39	0·9	0·67	

Unlike normal mineral dust deposited directly on a glass slide, asbestos deposited on a filter does not all lie in one plane (especially in the case of larger pore size filters). In order to view all the fibres, therefore, scanning must be done over a range of focal planes of the microscope. A failure to do this usually leads to undercounting by the inexperienced, although chrysotile fibres can twist in and out of a focal plane and be counted more than once. In one case, in this exchange, it was found that only one fifth of the fibres were counted because only one focal plane had been scanned.

A further difficulty was connected with the use of a phase contrast microscope. Some of the participants in the present exchange were unsure how to line up the phase rings within their microscope. Correct alignment, however, is critical in obtaining good agreement. In one establishment not involved in this exchange, counts were reduced by 50 per cent by misalignment of the rings.

There were also differences in visual acuity and thoroughness of searching for fibres near the limit of visibility; microscopists accustomed to counting easily-seen particles above a defined size limit (as customary for many mineral dusts) may not identify faint unresolved images of thin fibres as particles that should be counted.

In this exchange the participants were asked to record whether the counts were made over the whole field of view of the microscope or only in the area of the graticule grid (see next section). No analysis could be made of the significance of this factor, however, as its effect was masked by the large variations in readings arising from the inexperience of the counters.

TRIAL 2: SLIDE EXCHANGE BETWEEN EXPERIENCED LABORATORIES

Methods

The second trial was divided into two parts: one involving laboratories experienced in counting chrysotile asbestos and the other laboratories used to counting amosite. Five laboratories participated in this exercise; four took part in the exchange of chrysotile slides (F, G, H and K) and three in the amosite exchange (G, J and K). Two laboratories continuously engaged in counting both types of asbestos were included in both exchanges (G and K). Laboratories F and G took part in the exchange described in the first section of this paper. The following description applies to both the chrysotile and amosite exchanges.

Each of the participants was asked to supply one or more sets of three slides. Each set was to consist of a light, a medium and a dense slide (<1 fibre/grid, 1–5 fibres/grid, >5 fibres/grid, when using a normal graticule grid area of *c.* 10^4 μm^2, i.e. $\simeq 1/10$ of the full field area).* Before the slides were despatched to the Institute they were counted by the originating laboratory. At the Institute the slides were re-labelled to conceal their identity and then sent to the different participants. All slides were factory samples except those supplied by laboratory G which were UICC chrysotile.

Each set of three slides was counted by one other laboratory and then returned to the originator where a final count was made. The distribution of the slides was organised by the Institute and was unknown to the rest of the participants. The exchange plan followed an incomplete block design. This ensured that every possible

*Not all graticules used in the trial were of this size. Laboratory H used a graticule $\simeq \frac{1}{4}$ of the full field, and laboratory K used several different sizes.

pair of laboratories read one set of slides in common so that all could be directly compared.

The chosen design had a number of advantages over a procedure which required every laboratory to count every slide. Firstly it reduced the risk of disenchantment with the trial which might ensue if the number of slides to be counted was large, thus encouraging careful reading of the slides: (some laboratories were involved in both exchanges and suffered a correspondingly increased reading load). Secondly, the transport and handling of slides was minimised, reducing the chance of slide breakage or deterioration. Finally, the duration of the trial could be kept short ensuring that the possibility of a change in reading standards was small.

The participants were asked to follow their usual counting procedure and no constraints were imposed on the methods they could use. In this way it was hoped that the results would be typical of routine counting standards. Forms were supplied on which the laboratories were asked to give details of their microscopes (manufacturer, model, optical system, illumination and magnification) and counting methods (whether by counting selected grids, scanning continuously or intermittently across the filter or by some other method). Other forms were provided on which to record the counts obtained for each slide. Information was also asked about the time taken to count the slide and whether the slide was counted using the full field of view of the eyepiece or the area delineated by the grid of the eyepiece graticule.* It was hoped that the influence of these various factors on the counts could be investigated.

Results

The counts by each laboratory are shown in Tables 2 (a) and (b) for chrysotile and amosite respectively. Firstly, the initial and repeat counts were examined to ascertain whether the slides deteriorated over the period of the trial. Factors such as differences between apparatus and counting technique which might influence the counting levels were next investigated. Observations were then made on the inter-counter differences bearing in mind divergencies in technique and apparatus. Finally the data were analysed using a statistical model which included the important factors. As the counting trial between inexperienced laboratories has shown a greater variability for UICC chrysotile than for factory chrysotile, the analysis for the chrysotile exchange was carried out both including and excluding the UICC samples.

Slide deterioration and repeatability of counts

Table 3 shows the mean, minimum and maximum ratio of final to initial counts for each of the originating laboratories. There appears to be no obvious overall systematic difference. A *t*-test of the differences in the logarithms of the counts showed that there was no evidence of such an effect. The chrysotile results were found to be more variable than those of amosite (standard deviations of the (natural) log differences were 0·47 (0·26 excluding UICC samples) and 0·14 respectively). From these figures it can be inferred that, if there is no true systematic change and all variability is of random origin, ratios between 0·6 and 1·6 (0·77 and 1·33 excluding

*Henceforth 'grid method' will refer to the technique of counting using the slide area delineated by the grid of the eyepiece graticule and 'full field ' will be used when the full field of view of the eye-piece is referred to.

TABLE 2 (a). RESULTS OF SLIDE EXCHANGE BETWEEN EXPERIENCED LABORATORIES: REPORTED RESULTS FOR CHRYSOTILE ASBESTOS

Slide identification		Reported counts for each laboratory (10^3 fibres/cm^2)											
Originating laboratory	Density	F			G			H			K		
		1	2	3	1	2	3	1	2	3	1	2	3
F	Light	3·1 *f*		2·6 *f*		3·16 *f*							
	Medium	5·1 *f*		5·1 *f*		4·9 *f*							
	Dense	88·0 *g*		52·5 *g*		34·0 *g*							
F	Light	2·6 *f*		2·2 *f*								4·1 *g*	
	Medium	8·9 *f*		10·7 *f*								15·2 *g*	
	Dense	65·0 *g*		42·0 *g*								47·0 *g*	
G*	Light				1·62 *f*		2·64 *f*					10·5 *g*	
	Medium				72·0 *g*		59·0 *g*					157·0 *g*	
	Dense				52·6 *g*		143·0 *g*					80·0 *fg*	
H	Light					3·9 *g*		1·9 *g*		1·38 *g*			
	Medium					4·25 *g*		2·06 *g*		1·54 *g*			
	Dense					66·5 *g*		46·1 *g*		85·5 *g*			
H	Light		1·2 *f*					2·7 *g*		n.a.			
	Medium		1·7 *f*					3·1 *g*		n.a.			
	Dense		10·7 *f*					16·6 *g*		n.a.			
K	Light								1·82 *g*		2·29 *g*		n.a.
	Medium								9·05 *g*		15·9 *g*		n.a.
	Dense								33·5 *g*		59·0 *g*		

Key: 1. Initial count. 2. Count by recipient laboratory. 3. Repeat count by the originating laboratory. *f* Full field method of counting. *g* Grid method. n.a. No count available. *UICC.

TABLE 2 (b). RESULTS OF SLIDE EXCHANGE BETWEEN EXPERIENCED LABORATORIES: REPORTED RESULTS FOR AMOSITE ASBESTOS

Slide identification: Originating laboratory	Density	Reported counts for each laboratory (10^3 fibres/cm^2): G 1	G 2	G 3	J 1	J 2	J 3	K 1	K 2	K 3
J	Light		1·08 *f*		1·37 *f*		1·06 *f*			
	Medium		4·6 *g*		2·75 *f*		3·08 *f*			
	Dense		6.57 *g*		6·35 *f*		5·76 *f*			
J	Light				3·19 *f*		3·78 *f*		4·35 *g*	
	Medium				6·50 *f*		6·29 *f*		8·1 *g*	
	Dense				8·95 *f*		7·99 *f*		9·6 *g*	
K	Light		1·6 *f*					2·36 *g*		2·05 *g*
	Medium		6·1 *f*					10·1 *g*		10·8 *g*
	Dense		95·0 *g*					9·56 *g*		84·4 *g*

Key : 1. Initial count. 2. Count by recipient laboratory. 3. Repeat count by the originating laboratory. *g* Grid method of counting. *f* Full field method. n.a. No count available.

TABLE 3. MEAN, MINIMUM AND MAXIMUM RATIOS OF REPEAT TO INITIAL COUNTS FOR EACH LABORATORY AND EACH EXCHANGE

		Originating laboratory: F	G*	H	J	K	All
Chrysotile exchange	Mean	0·83	1·54	1·28	—	—	1·02
	Minimum	0·60	0·82	0·73	—	—	0·60
	Maximum	1·20	2·72	1·85	—	—	2·72
	n	6	3	3	—	—	12
Amosite exchange	Mean	—	—	—	0·95	0·94	0·95
	Minimum	—	—	—	0·77	0·87	0·77
	Maximum	—	—	—	1·18	1·07	1·18
	n	—	—	—	6	3	9

*UICC

UICC), and 0·9 and 1·2 would be expected for repeat counts 68 times out of 100 for chrysotile and amosite respectively. As there was no evidence that the final and initial counts varied systematically all results are employed in the following analysis. The greater variability for UICC chrysotile will again be noted.

The effects of counting techniques and different apparatus

Inspection of the data in Tables 2 (a) and 2 (b) shows that when slides were counted by both grid and full-field methods the grid counts were invariably the greater. This suggests that the counting technique should be taken into account when inter-laboratory reading levels are examined.

The time taken to count a slide was another factor of interest that could be studied although there were many missing values. The average time taken to count the chrysotile slides was 40 min (range 70–20 min) compared with 30 min (range 47–15 min) for the amosite; the longer counting time for the chrysotile did not appear to reduce the variability of the results mentioned earlier. No association could be found between the time taken and the count reported.

The effects of other factors concerned with counting methods and microscopes could not be examined because they were peculiar to the different establishments and could not be separated from the reader effect.

Comparison of laboratory counting standards

The counts made of the various laboratory pairs on the same slides are expressed as ratios in Tables 4 (a) and (b). Where both initial and repeat counts are available from the same laboratory, the geometric mean is used as that laboratory's count of the slide. The ratios in corresponding boxes to either side of the main diagonals of the Tables are reciprocals of one another derived from the same data, and are not independent. It will be noted that the ratios are not always mutually consistent, for example, the mean (all slides) ratio F : G (1·23) is not equal to the product of F : H (0·54) and H : G (0·55). This is due to differences in counting methods and to random errors. The 'Expected' values, derived from statistical analysis of the data as described later, are consistent.

It can be seen from Tables 4 (a) and (b) that the ratios of grid counts to field counts (g/f) are generally greater, and the f/g ratios lower, than the ratios of counts made by similar methods (g/g and f/f), in agreement with previous observations on the effects of counting method. There is some evidence that, for chrysotile, the difference between the ratios is greater for the light slides than for the medium and dense ones, but the data are insufficient for definite conclusions to be drawn. The further analyses to be described are based on all slides irrespective of density.

It is clear from Tables 4 (a) and (b) that laboratory K counts higher than the others, for in every case the mean (all slides) ratio of its count to that of other laboratories is greater than 1. The other results also show considerable variations and inconsistencies, much of which may be attributed to the use of different counting methods. By taking the counts where both laboratories used the same method, unbiased estimates are obtained. The geometric means of these g/g and f/f ratios are given in Tables 4 (a) and (b). In the chrysotile exchange K and F appear to have been counting the highest while H returned the lowest counts. In the amosite trial the results were much closer and there was little to choose between the three readers. Although these ratios indicate how the establishments compare, they still suffer from inconsistency. It has not yet been determined whether the differences between laboratories are random in origin or are due to true divergence in counting standards. To analyse the data further, the following model was fitted to the data from each exchange:

$$C_{ij} = S_i \times R_j \times T \times E_{ij} \qquad (1)$$

where C_{ij} is the observed count for slide i read by laboratory j,

S_i is the 'true' count for slide i,

R_j is a factor for laboratory j by which it is different from the 'true' count. This is constant for all slides,

T is a factor by which the count is altered if the grid method is used instead of the full field,

and E_{ij} accounts for the remainder of the variability which is assumed to be random

TABLE 4 (a). RATIOS OF COUNTS: CHRYSOTILE

			Laboratories forming the numerator of the ratio			
			F	G	H	K
Laboratories forming the denominator of the ratio	F	Light		1·11 (*f*/*f*)	2·27 (*g*/*f*)	1·71 *g*/*f*)
		Medium		0·96 (*f*/*f*)	1·82 (*g*/*f*)	1·56 (*g*/*f*)
		Dense		0·50 (*g*/*g*)	1·56 (*g*/*f*)	0·90 (*g*/*g*)
		Geom. mean. All slides		0·81	1·85	1·34
		Geom. mean. *g*/*g* and *f*/*f* only		0·81	—	0·90
		Expected		0·73	0·49	0·83
	G	Light	0·90 (*f*/*f*)		0·41 (*g*/*g*)	5·08 (*g*/*f*)
		Medium	1·04 (*f*/*f*)		0·42 (*g*/*g*)	2·41 (*g*/*g*)
		Dense	2·00 (*g*/*g*)		0·94 (*g*/*g*)	0·92 (*g*/*g*)
		Geom. mean. All slides	1·23		0·55	2·24
		Geom. mean. *g*/*g* and *f*/*f* only	1·23		0·55	1·49
		Expected	1·37		0·67	1·13
	H	Light	0·44 (*f*/*g*)	2·41 (*g*/*g*)		1·27 (*g*/*g*)
		Medium	0·55 (*f*/*g*)	2·39 (*g*/*g*)		1·75 (*g*/*g*)
		Dense	0·64 (*f*/*g*)	1·06 (*g*/*g*)		1·75 (*g*/*g*)
		Geom. mean. All slides	0·54	1·83		1·57
		Geom. mean. *g*/*g* and *f*/*f* only	—	1·83		1·57
		Expected	2·04	1·49		1·69
	K	Light	0·58 (*f*/*g*)	0·20 (*f*/*g*)	0·79 (*g*/*g*)	
		Medium	0·64 (*f*/*g*)	0·41 (*g*/*g*)	0·57 (*g*/*g*)	
		Dense	1·11 (*g*/*g*)	1·09 (*g*/*g*)	0·57 (*g*/*g*)	
		Geom. mean. All slides	0·75	0·45	0·64	
		Geom. mean. *g*/*g* and *f*/*f* only	1·11	0·67	0·64	
		Expected	1·21	0·88	0·59	

TABLE 4 (b). RATIOS OF COUNTS: AMOSITE

			Laboratories forming the numerator of the ratio G	J	K
	G	Light		1·11 (*f*/*f*)	1·37 (*g*/*f*)
		Medium		0·63 (*f*/*g*)	1·72 (*g*/*f*)
		Dense		0·92 (*f*/*g*)	0·94 (*g*/*g*)
		Geom. mean. All slides		0·87	1·31
		Geom. mean. *g*/*g* and *f*/*f* only		1·11	0·94
		Expected		1·19	0·94
Laboratories forming the denominator of the ratio	J	Light	0·90 (*f*/*f*)		1·25 (*g*/*f*)
		Medium	1·58 (*g*/*f*)		1·27 (*g*/*f*)
		Dense	1·09 (*g*/*f*)		1·14 (*g*/*f*)
		Geom. mean. All slides	1·16		1·22
		Geom. mean. *g*/*g* and *f*/*f* only	0·90		—
		Expected	0·84		0·79
	K	Light	0·73 (*f*/*g*)	0·80 (*f*/*g*)	
		Medium	0·58 (*f*/*g*)	0·79 (*f*/*g*)	
		Dense	1·06 (*g*/*g*)	0·88 (*f*/*g*)	
		Geom. mean. All slides	0·77	0·82	
		Geom. mean. *g*/*g* and *f*/*f* only	1·06	—	
		Expected	1·06	1·26	

and unassignable to any definable cause. By taking logarithms the model becomes:

$$c_{ij}=s_i+r_j+t+e_{ij} \qquad (2)$$

where the coefficients are the logarithms of the corresponding coefficients of equation (1). If the e_{ij} are assumed to be Gaussian distributed with zero mean and unknown standard deviation σ, and are independent of slide density, the coefficients in equation (2) can be estimated by least squares methods and their statistical significance investigated. Logarithms and geometric means were used in the preliminary analysis to ensure the data were treated uniformly with this model. In practice, the ratio, T, of grid to full field counts may not be the same for each counter. The design of the trial did not allow the estimation of separate T_j, however, since to do this would have involved asking the establishments to count the same slide by different methods. Applying such a constraint might have resulted in the values not being typical of routine counting.

Analysis of the chrysotile data using this model revealed that the grid method appeared to give counts about three times greater than full field values, i.e. $T = 3{\cdot}0$ (2·9 excluding UICC chrysotile). The probability that this finding is due to chance is small ($P<0{\cdot}1$ per cent). The ratio for the amosite data was smaller, 1·57, but again was found to be unlikely to be due to chance ($P<0{\cdot}1$ per cent).

Estimates of the R_j are listed in Tables 5 (a) and (b) for the chrysotile and amosite results respectively. These are the expected long-term ratios of the different reader's counts to the average level if all use the same method, i.e. all grid or all full-field. The probability that the differences found arose by chance is less than 5 per cent.

The R_j may be used to obtain ratios of the counts of individual laboratory pairs; these are the 'expected' values listed in Tables 4 (a) and (b).

The lower lines of Tables 5 (a) and (b) give the expected long term ratios of the laboratory counts to the average if the laboratories use the counting methods that

TABLE 5. EXPECTED LONG-TERM RATIOS OF LABORATORY'S COUNTS TO THE AVERAGE LEVEL

Counting method	Laboratory			
(a) *Chrysotile*	F	G	H	K
Same method throughout (R_f)	1·35 (1·32)	0·99 (1·16)	0·67 (0·68)	1·12 (0·95)
		All (f) or all (g)		
As in trial (light slides)	0·78 (0·78) (f)	0·57 (0·68) (f)	1·16 (1·16) (g)	1·95 (1·62) (g)
(b) *Amosite*	G	J	K	
Same method throughout (R_f)	0·96	1·14	0·91	
		All (f) or all (g)		
As in trial (light slides)	0·83 (f)	0·98 (f)	1·23 (g)	
As in trial (dense slides)	1·12 (g)	0·85 (f)	1·06 (g)	

Bracketed figures are calculated neglecting UICC samples

they employed in the trial. It can be seen that the variations between laboratories are greater than expected if all use the same counting method.

DISCUSSION AND CONCLUSION

In the trial between inexperienced laboratories, novice counters using only the published instructions obtained results which were of the order of half those of the standard laboratories for industrial samples and a quarter for UICC chrysotile asbestos. Following personal instruction, however, good agreement was obtained between all laboratories for industrial slides, and a greatly improved agreement (67 per cent) for UICC chrysotile.

This exchange showed that written instructions should emphasise the importance of scanning a full range of focal planes and the regular checking of phase ring alignment, and give guidance on the classification of problem fibres. Exchanges of sample slides and personal tuition clearly improves the consistency of counters, experienced as well as inexperienced.

In the second exchange the counting of fibres only within the grid area of the eyepiece graticule compared to using the full field of view was found to be of major importance, giving differences of 3× for chrysotile (2·9× excluding UICC) and 1·5× for amosite. This is possibly due to the greater resolution of the microscope in the central (grid) area compared with the periphery of the field. Perhaps an additional factor is that the smaller area can be studied more thoroughly and the positions of the fibres more easily remembered.

The difference between grid and full field counting found in the present trial may possibly have been accentuated by the wide range of slide densities deliberately introduced into the trial. It is unlikely to be the same in other situations with different samples and microscope optical systems.

Direct experimental verification of the effect for amosite was obtained by asking laboratory J to recount by the grid method three slides which they had previously counted 'full field'. The count was increased 1·5×, in agreement with the value of T found in the trial. Further work is desirable, especially with chrysotile.

The results of the trial indicate that the four experienced laboratories, using their normal (different) counting methods have somewhat different counting levels, the lowest and highest ratios to the mean being 0·57 and 1·95 (0·68 and 1·62 excluding UICC) for chrysotile, and 0·83 and 1·23 for amosite, respectively. It is estimated that if all laboratories adopted the same counting method the spread of the ratios would be from 0·67 to 1·35 (0·68 to 1·32 excluding UICC) for chrysotile, and 0·91 to 1·14 for amosite. This is approximately half the present spread for both chrysotile and amosite (two-thirds for chrysotile excluding UICC).

When two separate evaluations of the same slides were made by the same laboratories, the standard deviation of the (natural) log differences was 0·47 (0·26) for chrysotile and 0·14 for amosite. From this it can be inferred that, if there is no true systematic change and all variability is of random origin, ratios between 0·6 and 1·6 (0·75 and 1·3), and 0·9 and 1·2 would be expected for repeat counts 68 times out of 100 for chrysotile and amosite respectively. The inclusion of UICC samples greatly increased the variability of the chrysotile evaluations and reduced the inter-laboratory agreement for low density slides. For high density slides, however, the agreement was practically unchanged as was the grid factor, T.

The problems indicated by this relatively small-scale trial are being investigated further by the Institute and the member Companies of the Asbestosis Research Council. The results will be published shortly. It is anticipated that the ARC will revise its Technical Note 1 to include improved procedures suggested by this work.

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