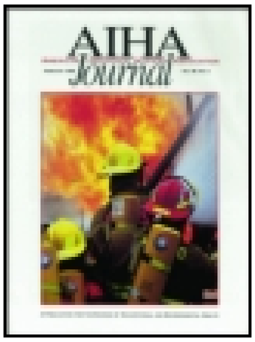

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LEON D. HOROWITZ

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NIOSH has recommended a Standard for Occupational Exposure to crystalline silica to OSHA with documentation based on dust count studies relating to health effects. This standard dictates sampling by mass respirable method only. A dual standard as in ACGIH-TLV list should be promulgated by OSHA which includes the dust count standard.

In defense of the dust count technique

LEON D. HOROWITZ
American Mutual Liability Insurance Company, Wakefield, Massachusetts 01880

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After many years of dust counting, industrial hygienists understandably are receptive to any change, if only for selfish reasons, to any method of evaluating the health hazard caused by free silica which would relieve the eyestrain and backbreaking microscope work associated with this technique.[1] Since the introduction of the mass respirable method for free silica evaluation, many technical papers have been written showing the development of the size selective gravimetric sampling techniques and the theories of respirable dust sampling, the studies relating gravimetric respirable dust concentration to midget impinger number concentrations as well as the various analytical techniques to analyze free silica in the respirable portion collected.[2-4]

All such technical papers related to the physical and technical problems of sampling and analysis, but no epidemiological studies relating the etiology of silicosis to the *mass* of silica were discovered during the research study of the literature for this paper. Since there were many questions concerning the reliability of the techniques and methods for analysis of free silica in the respirable portion using x-ray diffraction, colorimetric or infrared, as well as problems concerning microbalance capabilities and especially the high cost involved for these instruments and for multiple air sampling pumps plus increased times of sampling, many industrial hygienists who were using the time-proven method of dust counting in use for over 50 years opted to stay with that method until all of these problems were solved. Besides, the ACGIH annual TLV list, the OSHA Safety and Health Regulations, most State Occupational Health Departments and MESA[5,6] continue to list the crystalline quartz dust count TLV and it was economically imprudent to change to costly methods until the standard was finalized. Since they were concerned that the ACGIH would eliminate the dust count TLV from their annual list, the O.D. Subcommittee of the American Mutual Insurance Alliance wrote to Dr. Stokinger for reassurance that the Dust Count TLV would be kept on the list, and he *did* so very positively in a letter[7] to the subcommittee. Similar confirming letters were received by other TLV Committe members, Dr. M. R. Zavon, Dr. R. G. Smith, and Dr. H. B. Elkins.[7]

It was therefore with great curiosity that the industrial hygienists waited for the Crystalline Silica Document[8] to be published and were disturbed that it took almost 4 years (until November 1974) after passage of the OSHA Act of 1970 for the standard for this most ubiquitous of occupational disease hazards to be recommended by NIOSH to OSHA. They had hoped that perhaps the delay was caused

Leon D. Horowitz is Chief, Industrial Hygiene Section, American Mutual Liability Insurance Company in charge of the Industrial Hygiene Analytical Laboratory and industrial hygienists in the field. His previous experience has been with the New York State Division of Industrial Hygiene, several years as consultant and with industry. He is a registered Professional Engineer in New York, Pennsylvania, and Massachusetts as well as certified by A.B.I.H. and C.S.P.

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by more in-depth studies relating the disease to the proposed measurement of the physical property of mass. But as will be demonstrated later in this paper, this was not the reason for the delay. Some have been critical of NIOSH for their reluctance to keep those industrial hygienists in the field, who must implement health standards, informed concerning the progress of this criteria document. The president of the New England section of the AIHA requested NIOSH in January 1974 through proper channels, to send a speaker to the Massachusetts Safety Council to discuss the Silica Criteria Document[8] and was refused with the excuse that NIOSH could not discuss the standard *before* it was published. Undaunted (which is defined in Webster's as courageous with an undiminished resolution), the New England local section president asked Dr. John M. Peters of the Harvard School of Public Health, who was a review consultant for this Criteria Document,[8] to discuss the document. It was therefore at this meeting in March of 1974 that it was first revealed that the Criteria Document[8] was to be on crystalline silica, not on total mineral dust containing free silica; that the TLV would be 50 μg/cubic meter of free silica requiring x-ray diffraction on each personal 8 hour sample and that the dust count method would not be recommended at all. No more weighing of filters (what is one to do with the expensive microbalances?); no more TLV dust formulas and no more dust counts. This, of course, came as news to everyone and surely most of those reading this paper were not aware of this until the Criteria for a Recommended Standard for Occupational Exposure to Crystalline Silica[8] was finally released in November, 1974.

The essential premise in this defense of the dust count method is to object to the proposed promulgation in the Criteria for a Recommended Standard for Occupational Exposure to Crystalline Silica[8] of a permissible silica exposure based *only* on the mass concept and the rejection of the dust count concept upon which almost all health effects of silica exposure have been founded. There is no argument against NIOSH recommendation to OSHA that OSHA should use the mass concept of sampling and analysis for their compliance work. This, of course, is their own decision to make. However, if the standard is published in the Federal Register and only includes the mass respirable TLV, OSHA compliance officers will interpret this to mean that the sampling and analytical method that they specify is the only method which the employer or his representatives can use to meet the requirements for monitoring (sampling and analysis) of his own plant exposures and they will reject (and cite) those companies which choose to monitor their plants by equally valid methods which they may have been using for many years (such as the dust count method) or even the formula method for mass respirable samples specified in the ACGIH annual TLV list and new methods such as the respirable dust monitor which uses beta radiation absorption as the measurement principle, etc., any of which he may find more feasible to use because of cost of sampling and analysis as well as cost of personnel training.

Dust sampling procedures must be designed so that dust concentrations are measured accurately and consistently in order for such measurements to provide meaningful results; however, the sample collected must correspond closely to that on which hygiene standards are based. This Silica Document[8] states that "Ideally, the methods employed should be as closely related to the health hazard as possible." The dust count standard meets these requirements as shown by 18 pages of documentation under epidemiological studies in this Document[8] since almost every study reported health effects based on dust count environmental data (mostly in the Vermont granite shed industry).[8] The only studies mentioned using the mass concept were performed by the Harvard School of Public Health[9-11] and by Reno and Stratton[12] and the concept of a mass TLV of 50 $\mu g/m^3$ content was based on these studies. Animal toxicity studies (documented on 12 pages of this Document) are all based on dust counts and relationship of particle size to the disease silicosis.

Even the Basis for Recommended Environmental Standard which covers 11 pages of this document refers to numerous epidemiologic studies in metal mines and foundries which reveal that the medical data are reasonably consistent with impinger-count dust concentration data and that it is from the Vermont granite industry that the most extensive and complete environmental and medical data are available for establishing a recommended environmental limit for exposure to free silica from dust count data accumulated over 50 years. As stated in this Silica Criteria Docu-

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ment[8] "with the exception of the reports by Theriault et al, *all occupational environment* dust exposures were determined by *microscopic counts of impinger-collected dust samples*. The derived air dust concentrations in mppcf and the associated health effects provide the major portion of the material used as the present exposure limits (TLV) for quartz and other free silica polymorphs."

Based on the two comparison studies previously mentioned, a conclusion was made that 10 mppcf of granite dust (containing 25-35% free silica) was equivalent to 100 $\mu g/m^3$ of free silica. Theses 2 studies were based on comparing impinger count measurements with size selective mass concentration from granite worker environments in an attempt to establish a relationship between these methods of sampling free silica. Based on those few studies NIOSH then concluded, "Thus a safe level of 5 mppcf for the granite workers indicates a level of 50 μg/cu. meter in terms of respirable free silica," which is to be applied to all silica industries containing from 1% to 100% free silica.

Thus the object of the documentation in this recommended standard was to compare studies of size selective mass concentration with impinger count measurements which all previous studies used as a means to determine a safe limit in order to arrive at a mass respirable dust (TLV) of 50 $\mu g/m^3$ which is equivalent to the well documented safe limit of 5 mppcf which worked so well as a dust count limit for granite dust.

NIOSH apparently did a good job accomplishing this objective although it would seem that more comparison studies should have been made in other silica industries for better statistical accuracy. However, inadvertently they also very effectively documented the success of the dust count method as a monitoring means for eliminating silicosis in the Vermont granite shed. Nevertheless they neglected to recommend a dust count TLV since this was not their intent.

A more objective conclusion should be made after studying the considerable documentation in this proposed standard which would be as follows:

1. Dust control in the Vermont granite sheds has succeeded in reducing the incidence of silicosis with the aid of monitoring by the light field dust count impinger method using the TLV of 5 mppcf.
2. Some studies have indicated that size selective sampling using the mass respirable TLV value of 50 $\mu g/m^3$ is acceptable as an alternate or equivalent method of evaluation of exposure to crystalline silica.
3. Analysis of silica in the airborne respirable dust collected in the breathing zone of the worker is closely related to the health hazard due to inhalation of crystalline silica dust.

Since the dust count standard is the primary basis for a safe level of exposure to silica and the mass standard was chosen only by a comparison test with the dust count standard, it appears very arbitrary of NIOSH to have eliminated the dust count standard. The dust count method should be retained as an equally valid standard and method of evaluation of exposure to silica dust. At the very least, the final OSHA standard must specifically permit the employer to monitor his plant exposure by this or any other equally valid method if he so chooses.

The most consistent argument used against the dust count method has been that it is not reproducible. Interlab studies have shown significant deviations from different counters, etc. Nevertheless, the Criteria Document concludes that "impinger sampling combined with its microscopic counting method has served well in the past as a tool in reducing exposures to dusts which give rise to pneumoconioses." If inconsistency in counting is the reason for not including the dust count method in this document, it would appear that the asbestos standard should also be rejected based on two recently published papers in the February 1975 AIHA Journal[13,14] which indicate that individual variations of count data at a single facility are as high as 50% and permissible variations in the P.A.T.[15] program are as high as 90% from the mean. In fact, the P.A.T.[15] program so far has indicated significant deviations with silica mass determinations as great as those with dust counts also. The arguments against the dust count method, such as those shown on Page 80 of the document,[8] can also be used against the mass method. There is no consensus that x-ray diffraction is a reliably consistent method for silica analysis of silica bearing dusts in all dusty industries. In fact, it is reported that dust mixtures in many industries cause interference.

The need for careful training of people to count dust properly surely applies to x-ray diffraction technicians who may be more difficult to find. The cost of x-ray diffraction analysis is much higher than analysis of settled dust for free silica.

There are many questions concerning the reliability of the x-ray diffraction method which cause confusion for industrial hygienists. In a review of "Analytical Methods Used for the Determination of Free Silica Over the Past 35 Years", Robert G. Keenan of George D. Clayton Associates stated in one paper that he preferred to use x-ray diffraction for samples containing over 20 μg quartz on the filter; infra-red for analysis of respirable fractions of dust in the lightest samples (since limit of detection is 2 to 3 μg) and that he used the colorimetric method only if requested to do so. Table I shows the discrepancies in analytical data obtained by a single chemist on a much analyzed dust containing 25.39% free silica. However, NIOSH shows better correlation (on page 83 of the Criteria Document[8]) (See Table II) between 3 analytical methods used on granite shed dust samples. Figure 1 is a copy of the first page of the analytical method (P & CAM 109) recommended by NIOSH in their NIOSH Manual of Analytical Methods for x-ray diffraction. Note that this method is given a D operational classification. Figure 2 shows that the NIOSH classifications from the first page of this manual are defined and the class D operational classification is defined as "A Method in general use or approved by most professional industrial hygiene analysts, but has not been thoroughly evaluated by NIOSH or any professional societies." And still it is the method recommended by NIOSH in the Criteria Document.

The following is included to provide evidence beyond that of the documentation from the Criteria Document[8] which has been used in this paper up to now to support the recommendation for inclusion of the dust count method in the crystalline silica standard.

Aerosol sampling must give three kinds of information; the aerosol's concentration, composition and *particle size distribution. Particle size* is particularly important in evaluating the potential hazard.

The works of Drinker, Hatch,[16] Gross[17] and others have indicated that the percentage of particles smaller than 5μ which penetrate to the alveolar spaces of the lungs increases with decreasing particle size. The alveoli retain most of the 1 to 5 μ size particle which reach them.

Although the two stage size selective sampler[3] recommended for mass respirable sampling is a great achievement in the direction of sampling of only that fraction which penetrate the lower respiratory tract where the damage is done, the use of mass analysis does not respond to the effect of particle size and surface area as well as dust count does.

No simple measures of atmospheric exposures such as mass of material per cubic meter and the composition of the total airborne dust will necessarily provide a proper quantitative (hygienic) description of the aerosol cloud. So how should aerosol samples be collected, composition determined and concentration expressed?

TABLE I
Analysis of 200-mesh Foundry Dust Containg 25.39% Free Silica

ANALYSIS NUMBER	GRAVIMETRIC %	X-RAY DIFFRACTION: REDEPOSITED SAMPLE, EXTERNAL STANDARD %	COLORIMETRIC: USING AQUEOUS STANDARDS %	COLORIMETRIC: USING CRYSTALLINE QUARTZ STANDARDS (–5μ), DIGESTED %
1	24.6	32.0	16.0	25.5
2	24.6	26.2	18.9	30.1
3	25.0	28.8	15.3	24.4
4	—	32.1	15.3	24.4
5	—	29.9	—	—
Average	24.7	28.8	16.4	26.1

TABLE II
Percentage of Free Silica Recovered by Three Different Analytical Methods

ANALYTICAL METHOD	NUMBER OF SAMPLES	MEAN % FREE SILICA	% DEVIATION FROM OVERALL MEAN
Colorimetric	18	23.6	+0.9
Infrared	12	24.5	+5.0
X-ray diffraction	15	22.2	−5.0
	45	23.4 (overall mean)	

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Physical and Chemical Analysis Branch

Analytical Method

Analyte:	Quartz, Crostobalite, Tridymite	**Method No.:**	P&CAM 109
Matrix:	Atmospheric Dust	**Range:**	5–200 $\mu g/cm^2$
Procedure:	X-ray Diffraction		
Date Issued:	4/7/72	**Precision:**	$\pm$ 5 μg
Date Revised:	1/15/74	**Classification:**	D (Operational)

Figure 1–Free silica (quartz, cristobalite, tridymite) in atmospheric dust.

Physical and Chemical Analysis Branch
Division of Laboratories and Criteria Development

Class A—Recommended—A method which has been fully evaluated and successfully collaboratively tested by a selected group of laboratories.
Class B—Accepted—A method which has been subjected to a thorough evaluation procedure in the NIOSH laboratory and found to be acceptable.
Class C—Tentative—A method which is in wide use and which has been adopted as a standard method or recommended by another Government agency or one of several professional societies such as ACGIH, AOAC, AIHA, ASTM or ISC.
Class D—Operational—A method in general use or approved by most professional industrial hygiene analysts but has not been thoroughly evaluated by NIOSH or any professional societies.
Class E—Proposed—A new, unproved or suggested method not previously used by industrial hygiene analysts but which gives promise of being suitable for the determination of a given substance.

December 17, 1973

Figure 2–NIOSH classification of analytical methods.

This question was under consideration from the earliest days of systematic study of dust diseases. Greenburg & Bloomfield in U.S. Public Health Service studies of dusty trades reported dust concentration in terms of numbers of particles rather than by weight and were careful to exclude > 10 μ. They pointed out how misleading weight concentration could be since one 10 μ particle, for instance, contributes as much to the weight of the sample as 1,000 or more particles 1 μ in size, but does not contribute as much to the hazard. These and other considerations led to the early view that the most important particles contributing to the silicosis risk fall within the 1-3 μ range.

The weaknesses of the dust count method were well recognized by the early practitioners of the means for evaluating the relative dustiness of industrial atmospheric exposures. They were aware of the limits in accuracy and possibility of subjective responses. For this reason the limitation provided by the ACGIH-TLV list cautions that they should be used as guides in the control of health hazards and should not be used as fine lines between safe and dangerous concentrations. This provides the necessary precautions by all well trained industrial hygiene practitioners. With the passage of the OSHA Act, OSHA has chosen to ignore this limitation and has promulgated the whole of the 1968 TLV list as absolute TLV's and this, of course, is the crux of the problem today with all health standards, including silica.

The dust count TLV used as a guide has

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proved to be a very satisfactory method of measuring the degree of dustiness and for evaluating the dust exposure in relationship to the hazard as demonstrated so well in this Silica Criteria Document.

The fact that silicosis continues to be a problem is not due to the weaknesses of the dust count method, but is due to the lack of authority or the "will" to implement existing laws (or the lack of such laws in some states).

A new standard based on mass or any other basis will not eliminate the silicosis hazard. However, hopefully the work practices in a universally applied regulation such as OSHA standards which include monitoring by any equally valid method, can and will do so if only strictly implemented.

Both methods of measuring the degree of hazard are equally "good or poor", depending on one's subjective attitude, as an index of exposure; both give indication of the average exposure over a period of years since in most instances dustiness is subject to rapid fluctuations from moment to moment and from day to day. However, use of dust counts never pretended to be an absolute evaluation, but merely a measure of dustiness as a guide to control, while mass sampling is an attempt to meet an absolute standard for regulatory purposes.

Both methods have statistical problems complicated by the fact that the universe to be sampled is not stable, either in space or time. Although mass sampling is an attempt to resolve time weighted averaging which must be more tediously performed by the dust count method, the dust count method can be used to determine which cycle of operation contributes most to the overall TWA (time weighted average) exposure for purpose of controlling such source. The mass sample can only determine TWA exposure requiring further study (perhaps by relative short dust counts) to pinpoint the trouble source.

The aim of dust sampling and determination is not to measure the absolute dust concentration in air, but rather to obtain an index of the health hazard involved in breathing the dust laden air. Requirements are determined by physiological considerations and not by the physical criteria usually applied to precise instruments. A method that determines dust concentration only approximately (as both dust count and mass do) may still measure the silicosis producing potentialities of dust laden air with as great exactness as possible.

For routine dust determination as a control measure to be used by the employer or his representatives whose functions are not regulatory, local conditions should govern the choice of method and *practical* rather than *theoretical* considerations should be the guide in the selection of this method. Portability, convenience of operation, cost, and the time and skill required to collect and analyze the samples are important factors.

After review of the literature in the last 10 years evaluating the mass respirable method, all that can be conclusively said is that, "The evaluation of the potential silicosis hazard by a mass limit is not inconsistent with the judgment of the hazard based in impinger samples".[3] None of the research and papers have shown mass to be a better indicator of the hazard or that the dust count method is not as good a tool—only that mass sampling can be used as an alternative to impinger sampling and if so the corollary is also true and dust count can be used as an alternative to mass. The NIOSH recommended standard does not do this.

There are no studies to show that physical measurements of mass is a better parameter than particle size, number or surface area. If anything, the reverse is true.

The pros and cons of both methods can be argued back and forth for days depending on the experience, needs and motivations of those concerned. The important thing to remember is that there is no absolute means of measuring the hazard as so frequently stated in this and other criteria documents. Any one method (either dust count or mass) can be used effectively for evaluating the atmospheric exposure if it is consistent, fairly accurate and performed repeatedly in the same manner by the same well-trained technician.

Summary

The OSHA standard must specifically permit the employer to monitor his plant by the dust count method (or by any other equally valid method) as well as by the mass method if he so chooses. This would require the addition to the standard of a dust count TLV (as in the ACGIH List), as well as the mass respirable standard presently recommended by NIOSH in the Criteria Document.

In other words, a dual standard for free silica should be promulgated by OSHA.

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