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Workplace evaluation of a disposable respirator in a dusty environment

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Industrial hygiene sampling for total airborne particulate during the manufacture of a concrete patching compound revealed concentration estimates which exceeded the ACGIH TLV of 10 mg/m³. These results led to recommendations for the implementation of improved engineering controls and the initiation of a respiratory protection program on an interim basis. The 3M 9910 disposable respirator was selected for use based upon a knowledge of existing total dust concentrations and a review of assigned protection factors for the various classes of respiratory protective devices.

A follow-up evaluation by NIOSH investigators revealed that use of 3M 9910 respirators reduced total dust exposures to levels considered to be acceptable, but that the assigned protection factor derived from a set of workplace protection factors was less than anticipated. The results of this study suggest the need for in-mask sampling after the implementation of respiratory protection to ensure, in a direct manner, that the particular respirator in service provides at least the minimum level of protection assigned to its class. A practical method for determining an assigned protection factor from a set of workplace protection factors is described which can be easily used by industrial hygienists to establish assigned protection factors for the particular conditions of respirator usage existing at their own facilities. **Reed, L.D.; Lenhart, S.W.; Stephenson, R.L.; Allender, J.R.;** Workplace evaluation of a disposable respirator in a dusty environment. *Appl. Ind. Hyg.* 2:53-56; 1987.

Introduction

Personnel of the National Institute for Occupational Safety and Health (NIOSH) have conducted two health hazard evaluations at the request of the management of a rehabilitation sheltered workshop located in the midwest.[1,2] The primary function of the workshop is the occupational rehabilitation of physically and mentally handicapped adults. Clients are referred to the facility from state hospitals or the state department of mental health.

Twelve workshop clients and two supervisors are employed to mix and package a concrete patching compound. The manufacturing process consists of mixing Portland cement, iron powder, gypsum, sodium chloride, ammonium chloride, and a detergent in a mechanical mixer. Once the powdered ingredients are blended sufficiently, the final product is packaged in plastic tubs, each containing five pounds of material. A maximum production of approximately 3,000 pounds of material can be produced during a six-hour work shift.

The first health hazard evaluation conducted by NIOSH personnel at the workshop investigated the occurrence of cases of benign breast tumors among both current and past female staff members.[1] After completing surveys at the facility in February 1982 and in March 1983, NIOSH researchers concluded that no evidence could be found to link the occurrence of benign breast tumors with exposure to any of the substances encountered in the manufacturing process. However, because certain job tasks were associated occasionally with levels of total airborne particulate exceeding the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV), recommendations were made to implement the use of improved engineering controls and to initiate, on an interim basis, the use of respiratory protection.

Air sampling for respirable particulate performed during the first NIOSH health hazard evaluation resulted in a concentration range of 0.5 to 2.3 mg/m³, while air sampling for total particulate resulted in a concentration range of 1.7 to 34 mg/m³. Based upon the results of sampling for total particulate and the attendant need for reducing potential exposures to levels less than the TLV of 10 mg/m³ recommended by ACGIH,[3] selection of respiratory protection with an assigned protection factor of at least five was suggested. The 3M 9910 dis-

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posable respirator was selected to protect workers from over-exposure to total airborne particulate. The class of respirator to which the 9910 belongs has been assigned a protection factor of five by NIOSH[4] and ten by the American National Standards Institute (ANSI).[5] In order to confirm the appropriateness of this respirator selection, a second NIOSH health hazard evaluation was conducted in February 1984. This second evaluation was a workplace protection factor study of the 3M 9910 respirator involving the simultaneous collection of personal samples and in-mask samples. A workplace protection factor[6] is a measure of the effectiveness of a properly functioning and properly used respirator. The purposes of this article are to report the sampling results which were achieved during the second NIOSH study and to describe a practical method for determining an assigned protection factor from a set of workplace protection factors.

Methods

During the February 1984 follow-up study, seven workshop clients volunteered to participate in an evaluation of the 3M 9910 disposable respirator. A total of 22 pairs of samples were collected over a three-day testing period. Three of these pairs were collected during clean-up operations at the end of the third day of testing; the remaining pairs were collected for as much of the workers' six-hour work shift as was possible.

Concentrations of total particulate both outside and inside the respirator were measured simultaneously with two separate sampling trains while each study participant was engaged in normal work activities. Each sampling train consisted of a 37 mm two-piece closed-face Millipore cassette containing a pre-weighed 0.5μm pore size polyvinyl chloride filter and an AP10 support pad and connected by Tygon tubing to a DuPont P2500 constant flow personal sampling pump calibrated to 2 lpm. All filter media were desiccated for 72 hours both before and after sampling, and were weighed to the nearest 0.01 mg.

The filter cassette of the first sampling train was attached to the shirt lapel of each participating worker to collect a sample representative of the total particulate exposure that would have been experienced had the worker not been wearing a respirator. The filter cassette of the second sampling train was connected to an inlet probe inserted through the respirator so as to collect an in-mask sample at a location approximately between the nose and upper lip. The sampling efficiency of the inlet probe has been experimentally defined.[7] While it was not possible to quantify the influence of the in-mask sampling flow rate upon the concentration estimates presented in this article, we believe that a sampling flow rate of 2 lpm is too low to affect this study's overall results significantly.

Quantitative facepiece fit testing was conducted using a Dynatech Frontier portable instrument prior to the start of each work shift to check for gross leakages. Respirators and sampling trains were always donned and removed in a dust-free area separate from the actual area of production. Sampling pumps were started after a respirator was completely donned and were stopped before a respirator was removed. Each worker was instructed not to remove or manipulate the respirator during testing, and, to ensure that this requirement was followed, each worker's activities were monitored continually.

Eight area samples were collected using Marple cascade impactors operating at a flow rate of 2 lpm to determine particle size distributions for three locations of the work area. The three sampling locations were 1) at a distant corner of the work area, 2) beside the small mechanical mixer, and 3) on the packaging table. Of the eight area samples collected, three samples were collected at location 1, three samples were collected at location 2, and two samples were collected at location 3.

TABLE I
Total particulate concentrations and workplace protection factors for personal samples

Worker	Sampling duration (minutes)	Particulate concentration (mg/m³) Lapel	In-mask	Workplace protection factor: (lapel concentration / in-mask concentration)
	Day 1 (January 31)			
1	207	23	1.9	12 (± 2)
2	222	11	0.3	37 (± 5)
3	267	12	7.5	1.6 (± 0.2)
4	266	40	1.2	33 (± 5)
5	244	2.6	0.3	8.7 (± 1)
6	239	8.4	0.4	21 (± 3)
	Day 2 (February 1)			
1	266	27	4.1	6.6 (± 0.9)
2	239	18	0.5	36 (± 5)
3	269	23	0.7	33 (± 5)
4	155	53	1.1	48 (± 7)
5	226	3.5	0.3	12 (± 2)
6	233	12	2.4	5.0 (± 0.7)
7	264	16	0.4	40 (± 6)
	Day 3 (February 2)			
2	246	38	0.5	76 (± 11)
3	278	16	1.9	8.4 (± 1)
4	258	44	0.3	150 (± 21)
5	238	6.3	1.4	4.5 (± 0.6)
6	256	12	1.2	10 (± 1)
7	237	8.9	0.2	44 (± 6)

Values in parentheses are to be used for obtaining 95% confidence limits.

Results and discussion

Impactor sampling produced the following results. Mean concentrations (mg/m³) and mean aerodynamic mass median diameters (μm) of total particulate at the distant corner of the work area, beside the mixer, and on the packaging table were 3.7 and 8.0, 3.7 and 8.7, and 16 and 20, respectively.

The results of personal sampling are shown by Tables I and II. Lapel and in-mask concentration estimates are presented in the center two columns of each table. Workplace protection factors, the ratio of these two estimates (lapel/in-mask), are presented in the last column of each table. These results are uncorrected for an effect which may cause an overestimation of workplace protection factors. Because of lung deposition, in-mask concentrations are lower during exhalation than during

TABLE II
Particulate concentrations and workplace protection factors for personal samples during cleanup

Worker	Sampling duration (minutes)	Particulate concentration (mg/m^3) Lapel	In-mask	Workplace protection factor: (lapel concentration / in-mask concentration)
2	19	102	6.0	17 (± 2)
3	13	64	11	5.8 (± 0.8)
6	17	44	2.7	16 (± 2)

Values in parentheses are to be used for obtaining 95% confidence limits.

inhalation. Therefore, average in-mask concentrations measured during this study are lower than the true inhaled dust concentration. For the purpose of this study, this effect is considered insignificant.

With regard to the data of Table I, it is important to observe that although the majority of lapel concentrations exceeded the TLV for total nuisance particulate, none of the in-mask concentrations did. The 19 lapel samples have a geometric mean concentration of 15 mg/m^3 with a geometric standard deviation of 2.3. By comparison, the corresponding in-mask concentrations have a geometric mean concentration of 0.8 mg/m^3 with a geometric standard deviation of 2.7. Therefore, the observed reduction in total in-mask dust exposure suggests that the selection of the 3M 9910 respirator for this application reduces exposure.

As is evidenced by the lapel concentrations shown in Table II, dry sweeping during cleanup generated much higher concentrations than would be expected if high efficiency vacuum cleaning equipment were used instead. The elimination of dry sweeping in favor of vacuuming should substantially decrease the airborne concentration of particulate during cleanup.

Workplace protection factors have been used to evaluate the appropriateness of assigned protection factors for various types of respiratory protective equipment.[8-10] The workplace protection factors achieved during this study and shown in Table I were found to be described adequately by the log-normal probability distribution shown by Figure 1. The 19 workplace protection factors have a geometric mean of 18 and a geometric standard deviation of 3.1. Plotting of the 19 workplace protection factors on Figure 1 was accomplished using a previously published table of plotting positions for probability paper that has received wide acceptance.[11] The regression line of best fit shown on Figure 1 was fitted to the points (16%, 5.8), (50%, 18), and (84%, 56) representing the geometric mean workplace protection factor of 18 and values for one geometric standard deviation from the geometric mean (18/3.1 = 5.8 and 18 × 3.1 = 56).

One practice for defining an assigned protection factor has been to do so in terms of a specified proportion of workplace protection factors; this proportion is usually specified as 95%.[9] Assigned protection factor, PF_a, can be calculated from the following equation when, as in this case, the distribution is log-normal.

$$PF_a = PF_w/(S_g)^z$$

In this equation, PF_w is the geometric mean of the measured workplace protection factors, S_g is the geometric standard deviation, and z is the value corresponding to the selected proportion of workplace protection factors. The value 1.64 corresponds to the selected proportion of 95% and was taken directly from a table of cumulative probabilities and percentiles of the standard normal distribution.[12]

Using the equation, the assigned protection factor for the workplace protection factors of Table I would be given by

$$PF_a = 18/(3.1)^{1.64} = 3$$

The same result is achievable by reading directly the workplace protection factor at the 5% probability level from Figure 1.

Conclusion

Assigned protection factors can be useful to distinguish the relative performance of different respirator classes and thereby aid in the initial selection process.[13] However, assigned protection factors are used together with the results of lapel sampling to evaluate indirectly a respirator's performance under actual workplace conditions. A more direct measurement of a respirator's performance can be made by collecting in-mask samples and comparing these results with the results of lapel samples to determine workplace protection factors.

Because high concentrations of airborne particulate were present in the manufacturing area of the test site,

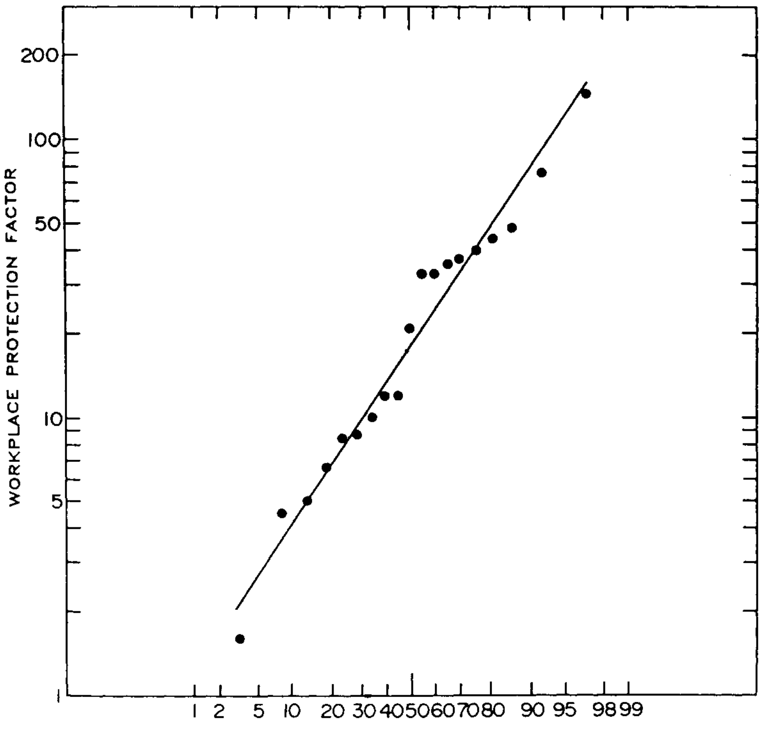

Figure 1—Log-normal probability plot of workplace protection factors.

researchers recommended that workers wear a brand of disposable respirator to reduce exposures to acceptable levels until improved engineering controls could be installed. This recommendation was based upon review of the results of industrial hygiene sampling and a review of published lists of assigned protection factors for various classes of respiratory protective devices.(4,5)

A later evaluation of the actual protection provided by the respirator selected for this application revealed that the assigned protection factor derived from the set of workplace protection factors was less than the NIOSH assigned protection factor of five and the ANSI assigned protection factor of ten for this respirator class. More importantly, however, full-shift in-mask concentration estimates did not exceed the TLV for nuisance particulates.

Recommendation

The results of this study suggest the need for in-mask sampling after the implementation of respiratory protection. Such follow-up sampling must not be limited to lapel sampling alone, but must include the determination of both in-mask and lapel concentration estimates in order to characterize the actual protection provided to workers wearing respiratory protection. Simultaneous in-mask and lapel sampling should be performed on a routine basis to ensure that there have been no significant changes in the conditions of respirator usage which would reduce the effectiveness of the particular respirator in service.

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Disclaimer

Mention of a company name or product does not constitute endorsement by the National Institute for Occupational Safety and Health (NIOSH).

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The centered high-mounted brake light: a human factors success story

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We practitioners of human factors are able to point to a number of success stories. These are situations where the application of human factors resulted in measurable and sizable improvements in the performance of systems or the safety of people, and/or reductions in the costs of developing and supporting systems. The number of such events that are readily identifiable, however, is probably not as great as we would desire. If we do our job right and effectively integrate the personnel component into systems, an obvious payoff in terms of accrued benefits of human factors should result. Unfortunately, it is often difficult to identify, much less quantify, the payoff of human factors application where the human factors input is embedded in the system development.

A case in which the benefit of human factors is both readily apparent and quantified is that of the centered high-mounted brake light. Most people have no doubt noticed the presence of this component on all 1986 passenger cars sold in this country. It may be less well known, however, that the regulation requiring this light was the result of research conducted by human factors practitioners in the area of transportation safety.

According to the U.S. Department of Transportation (DOT), rear-end accidents comprise 25% of all multivehicle accidents and 7.4% of fatal accidents. Within the overall objective of reducing the frequency of motor vehicle accidents in general, and rear-end accidents in particular, rear lighting and signaling on motor vehicles has been a subject of theoretical, laboratory, and simulation studies since the late 1960s. Based on these investigations, a number of suggestions have been formulated for improving rear lighting systems by modifying color coding, number of lamps, lamp location, and other design parameters. Early work in these areas was done by

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