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Prediction of 8-Hour Noise Dose from Brief Duration Samples

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Abstract

The purpose of this study was to determine whether brief duration samples of noise dose measurements could predict the noise exposure levels of employees as measured by 8-hour dosimetry. Sampled noise dose measurements were obtained for 1, 5, 10, 15, and 20 minutes and 8 hours for four workers at each of four industrial sites. Statistical analyses indicated no significant differences or interactions among trials and sample durations. A simple linear prediction model provided the best fit for the four shortest of the five abbreviated sample durations, whereas an exponential regression model provided the best predictions using the 20-minute sample duration. The high variance and low correlations across all measures permitted only poor predictions from these abbreviated sample data. Based on these results, sampled noise measurements of short duration (1 to 20 minutes) do not appear to be a valid means for predicting the amount of noise exposure during an 8-hour shift.

Key Words: Dosimetry, noise exposure, noise measurement, reliability

The noise dosimeter is a special purpose L_{eq} meter that measures, in percentages, the maximum allowable noise exposure over an 8-hour period as specified by the Occupational Safety and Health Administration (OSHA). Equivalent level or L_{eq} is a time-weighted energy average. It represents the total sound energy present in a measurement location over a given period of time, as if the sound was unvarying in its intensity parameters (Lipscomb, 1988a). OSHA also requires that the sound level exposure of workers in environments be described by a single number description, the noise dose. OSHA specifies a maximum daily noise (D) of unity:

$$D = \frac{C_1}{T_1} + \frac{C_2}{T_2} \cdots + \frac{C_n}{T_n}$$

where C equals the total exposure at a given steady dBA level, T equals the maximum allowable exposure time at that level during an 8-hour workday. The measurement of noise exposure must include all noise signals between 80 and 130 dBA. The choice of monitoring technique is left to the employer depending upon the uniqueness of their particular situation, although the average noise dose of an employee in a high noise environment can be measured more accurately by using area monitoring dosimeters rather than by using hand-held sound level meters (Feldman, 1985). When noise levels are not distributed uniformly over the working area, those employees working in close proximity to noisy machines can receive considerably higher doses than indicated by the area monitors. Personal dosimeters also help to estimate actual noise dose received by individual workers as they moved across different noise environments during the course of their shift (Cheremisinoff and Ellerbusch, 1982).

In the current economy, many companies are looking for cost-containment while maintaining adequate safeguards for their employees and improving the quality of their products or services. The application of dosimetry to determine every employee's level of noise expo-

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sure is a practical impossibility, and many manufacturers are seeking methods to obtain noise dose data without depending on 8-hour measurements. One possible means to achieving this goal is to predict 8-hour noise dose from abbreviated samples of dosimetry measurements. Lipscomb (1988b) believed that if the sound levels at work stations were sampled for 60 seconds repeatedly throughout a workshift, it would not be uncommon to discover that the averaged measures did not vary more than 1 or 2 dB. Many of the high-low sound amplitude cycles were repeated within the time span of 1 minute in many industrial noise environments. The purpose of this study was to examine the predictive value of the noise dosimeter in estimating noise exposure of employees by comparing 1-, 5-, 10-, 15-, and 20-minute samples to the customary 8-hour measurement. Can brief samples of noise measurements accurately predict the noise exposure levels of employees measured by 8-hour dosimetry?

METHOD

Facilities

A total of 16 employees from three companies participated in this study. Company A was a manufacturer of yard terminal and port tractors, fire truck and refuse truck chassis in northeast Kansas (Standard Industrial Classification Code 3537/3711, Kansas Department of Publications, 1990). It employs approximately 275 individuals. Dosimetry measurements were obtained at one central site for this company. Company B was a provider of electrical power service to the southeast and south-central areas of Kansas (Standard Industrial Classification code 50631/5052, Kansas Department of Publications, 1990). It employs approximately 1316 individuals. Dosimetry measurements were obtained at two sites for this company. The first site consisted of several locations because the noise dose measurements were made for a mobile construction crew. The crew was assigned to dig holes for the company's power poles and to string power cables between these poles during the day of the noise dose measurements. The second site was located within a power generating plant. Company C was a fabricator of structural steel for high-rise buildings and auto plants in northeast Kansas (Standard Industrial Classification code 3441, Kansas Department of Publications, 1990). It employs approximately 100 individuals. Dosimetry was measured at the one central site within this company.

Instrumentation

The DuPont Mark I (MK-I) Audio Dosimeter was obtained from the Wichita office of OSHA and used as the noise-measuring instrument for the 8-hour dosimetry. It calculates dose, stores the maximum sound level exposure, tracks operating time, and computes the average decibel level. This unit met all current US government specifications for audio dosimeters, including the requirements of OSHA, the Mine Safety and Health Administration, the Department of Defense, as well as ANSI S1.25-1978. The Mark I Audio Dosimeter was calibrated with an acoustic calibrator according to the manufacturer's specifications by the manufacturer and at the regional OSHA office just prior to the experiment.

The Metrosonic db-307 Noise Dosimeter and Integrating Sound Level Meter was used as the noise sampling measuring instrument. The Metrosonic db-307 functions as a digital sound level meter and personal dosimeter. It computes sound level as well as noise dose and projects the 8-hour noise dose. The instrument has sufficient storage capacity to remain on station for the life of the battery, typically over 50 hours. The eight-character alphanumeric LED display provides an on-the-spot readout of measurement parameters and all acoustic computations. The Metrosonic db-307 was calibrated with an acoustic calibrator according to the manufacturer's specifications by the manufacturer and by the regional OSHA office just prior to the experiment.

After obtaining both instruments from OSHA and prior to all field measurements, the microphones of both dosimeters and a precision sound level meter were placed in the center of the sound field within a sound-treated booth meeting the ANSI S3.6-1977 criteria for permissible ambient noise for audiometric testing. Delivering a white noise at a level reading 90 dB on the A scale of the sound level meter for a period of 8 hours, the daily noise dose of both dosimeters were within 1 percentage point of 100 percent noise dose and 0.3 percent of each other. These measurements were repeated after all field measurements, and the results did not vary by more than 0.1 percent from the initial readings.

Procedure

Prior to all measurements, the batteries within each dosimeter were checked to determine if it had sufficient power to operate the dosimeter (at the time they were obtained from the OSHA office each dosimeter received new batteries). The Mark I dosimeter was clipped onto the employee's belt and, for added security, the cable was threaded underneath the worker's outer clothing. The microphone was clipped to the collar and set to point upward as much as possible. The employee wore the dosimeter through an 8-hour shift. The experimenter randomly sampled each of the employee's noise levels at intervals of 1, 5, 10, 15, and 20 minutes using the Metrosonic db-307. This was accomplished by holding the microphone of the db-307 within 2 inches of the Mark I microphone. The data were recorded on a form for later reduction and analysis.

Data Analysis

Sampled noise measurements of 1, 5, 10, 15, and 20 minutes as well as 8-hour measurements were obtained for 16 subjects. Correlation and regression analyses were applied to provide statistical predictions among the five abbreviated and 8-hour noise dose samples.

RESULTS

Sampled noise dose measurements were obtained for 1, 5, 10, 15, and 20 minutes in addition to the 8-hour dosimetry measurement for four workers at four industrial sites within the three companies. Each brief-duration measurement was recorded four times throughout an 8-hour shift for 14 subjects and three times for 2 subjects (both employed at the same site) for a total of 62 trials. The means and standard deviations of the sampled noise dose measurements obtained for each subject are presented in Tables 1 through 4. Table 5 presents the means and standard deviations for each individual trial and across all measurements. Statistical analyses using two-way analysis of variance (ANOVA) with repeated measures on both the trial and sample duration data indicated no significant differences across the trials and across the five sample durations ($p < .05$). There also were no significant interactions across the trials and abbreviated sample durations data.

Correlation and simple regression model analyses were computed for each sample duration with the 8-hour percentage noise dose measurements. The coefficient of determination (r^2) values for seven simple regression analysis models applied to the data are presented in Table 6. The correlation coefficients for all of the best fit relationships were low and not statistically significant. In addition, all regression models for all abbreviated percentage noise dose measurements had low coefficients of determination, suggesting very poor predictive power for the sampled noise dose measurements regardless of which model was used.

Table 1 Means and Standard Deviations* of Percentage Noise Dose Measurements across Sample Durations for Individual Subjects at Company A

	Samples					
Subjects	*1 Min*	*5 Min*	*10 Min*	*15 Min*	*20 Min*	*% Dose*
Subject 1						
Mean	83.00	92.33	169.70	175.70	181.00	102.20
SD	18.25	18.93	116.90	126.50	139.80	
Subject 2						
Mean	94.33	127.00	96.33	95.00	96.00	83.70
SD	53.27	30.81	67.21	65.80	58.92	
Subject 3						
Mean	135.00	204.70	215.00	221.30	228.70	130.60
SD	62.35	16.04	12.00	12.50	13.65	
Subject 4						
Mean	67.33	110.00	153.70	119.30	52.33	492.00
SD	45.65	75.44	129.00	88.95	43.66	

*Based on four samples.

Table 2 Means and Standard Deviations* of Percentage Noise Dose Measurements across Sample Durations for Individual Subjects at the First Site of Company B

	Samples					
Subjects	*1 Min*	*5 Min*	*10 Min*	*15 Min*	*20 Min*	*% Dose*
Subject 1						
Mean	84.75	60.25	58.75	50.75	48.25	32.90
SD	60.64	37.54	31.91	33.16	38.77	
Subject 2						
Mean	48.50	43.00	57.25	61.50	56.50	47.00
SD	38.72	22.88	33.81	34.76	30.88	
Subject 3						
Mean	92.50	94.40	72.57	71.83	65.93	21.80
SD	150.30	85.00	57.94	58.94	53.78	
Subject 4						
Mean	20.00	35.25	40.50	45.50	47.00	179.00
SD	14.65	28.74	33.81	31.54	24.62	

*Based on four samples.

Table 3 Means and Standard Deviations* of Percentage Noise Dose Measurements across Sample Durations for Individual Subjects at the Second Site of Company B

	Samples					
Subjects	*1 Min*	*5 Min*	*10 Min*	*15 Min*	*20 Min*	*% Dose*
Subject 1						
Mean	17.00	18.00	21.43	29.25	34.50	254.00
SD	19.30	21.28	18.84	21.75	18.63	
Subject 2						
Mean	29.50	43.75	36.75	37.50	42.00	42.60
SD	28.52	29.67	13.89	13.40	23.17	
Subject 3						
Mean	41.25	61.50	70.50	79.00	84.50	59.90
SD	39.54	34.86	44.07	52.04	47.04	
Subject 4						
Mean	22.00	20.00	21.00	24.75	26.00	43.60
SD	24.49	19.41	16.63	20.11	17.64	

*Based on four samples.

The regression statistics pertaining to the best fit model for each sample duration across all trials are presented in Table 7. For the 1-minute, 5-minute, 10-minute, and 15-minute samples, the linear regression model provided the best fit to the data. Figures 1 through 4 illustrate the scatterplots and the line of best fit for these samples. The linear regression analyses for each of these sampling durations indicate weak, positive rectilinear trends that are characterized by high variance and large stan-dard errors of estimates. These data indicate very poor predictive value for the brief-duration sampled noise dose measurements. In contrast to the shortest sample durations, an exponential regression model provided the best fit to the data obtained from the 20-minute samples of percentage noise dose. Figure 5 illustrates the scatterplot and the line of best fit for the 20-minute sample data. The regression line indicates a moderate, positive exponential trend, but this analysis was also characterized by high variance within the data and large standard error of estimates, therefore indicating poor predictive value for the 8-hour prediction when using the 20-minute sample data.

Table 4 Means and Standard Deviations* of Percentage Noise Dose Measurements across Sample Durations for Individual Subjects at Company C

	Samples					
Subjects	*1 Min*	*5 Min*	*10 Min*	*15 Min*	*20 Min*	*% Dose*
Subject 1						
Mean	74.75	78.75	87.25	94.00	90.00	130.00
SD	30.26	18.52	13.15	9.93	8.83	
Subject 2						
Mean	280.30	300.00	360.00	386.00	375.00	431.00
SD	467.80	316.70	396.30	421.00	387.00	
Subject 3						
Mean	50.50	89.75	96.75	103.50	106.00	135.60
SD	12.12	35.98	28.92	38.79	37.18	
Subject 4						
Mean	184.00	184.00	162.00	144.00	148.50	174.00
SD	111.60	73.91	61.02	46.33	47.21	

*Based on four samples.

Table 5 Means and Standard Deviations* of Percentage Noise Dose Measurements for Individual Trials and across all Measurements

	Samples					
Trials	*1 Min*	*5 Min*	*10 Min*	*15 Min*	*20 Min*	*% Dose*
Trial 1						
Mean	66.25	111.87	139.12	143.25	132.93	147.40
SD	64.40	149.78	201.49	216.46	186.22	138.40
Trial 2						
Mean	114.53	113.51	125.15	120.59	116.67	147.50
SD	236.10	127.92	138.93	137.60	158.10	138.40
Trial 3						
Mean	75.50	81.50	80.31	84.37	82.81	147.50
SD	71.47	66.69	58.30	57.80	59.34	138.40
Trial 4						
Mean	66.18	52.47	49.50	53.70	57.39	126.20
SD	83.41	50.30	44.49	46.61	50.21	112.30
All measurements						
Mean	81.83	95.31	104.63	106.33	103.47	145.92
SD	135.76	109.88	133.17	138.56	131.99	131.88

*Based on four samples.

DISCUSSION

The purpose of this study was to determine whether brief-duration samples of noise measurements could accurately predict the noise exposure levels of employees as measured by 8-hour dosimetry. Sampled noise dose measurements were obtained for 1, 5, 10, 15, and 20 minutes in addition to 8-hour dosimetry measurements for four workers at each of four industrial sites. The large standard deviations within and across samples and the large standard error of estimates led to very low correlations and poor predictions across the sampled measurements and the 8-hour percentage noise dose. The extremely high variance and low correlations observed in these data did not lend themselves to suggesting any useful trends in the measurements. Rather, these data indicate that sampled noise measurements of between 1 and 20 minutes do not provide reliable and valid predictions regarding the amount of noise

Table 6 Coefficient of Determination (r^2) for Seven Simple Models of Regression Analysis

Regression Model	*Unadjusted Coefficient of Determination (r^2) for Sample Durations*				
	1 Min	*5 Min*	*10 Min*	*15 Min*	*20 Min*
Linear $y = ax + b$	0.0586	0.1349	0.1692	0.1503	0.1079
Power $y = b(x^a)$	0.0000	0.0320	0.0530	0.0829	0.0815
Exponential $y = b(10^{ax})$	0.0430	0.1164	0.1422	0.1315	0.1104
Logarithmic $y = a(\ln x) + b$	0.0000	0.0205	0.0399	0.0559	0.0301
Hyperbolic 1 $y = (a/x) + b$	0.0000	0.0029	0.0048	0.0001	0.0143
Hyperbolic 2 $y = \frac{1}{b + ax}$	0.0176	0.0651	0.0857	0.0829	0.0798
Hyperbolic 3 $y = \frac{x}{b + ax}$	0.0000	0.0010	0.0029	0.0039	0.0680

Table 7 Linear Regression Analysis for the Brief Duration and 8-Hour Percentage Noise Dose Measurements

Measurement	*Regression Analysis Samples*				
	1 Min	*5 Min*	*10 Min*	*15 Min*	*20 Min*
Regression Analysis					
Model	Linear	Linear	Linear	Linear	Exponential
Equation	$y = 0.24x + 126.63$	$y = 0.44x + 103.86$	$y = 0.41x + 103.24$	$y = 0.37x + 106.64$	$y = 80.59\,(10^{0.002x})$
Determination Coefficient (r^2)	0.06	0.13	0.17	0.15	0.11
Correlation Coefficient (r)	.24	.37	.41	.39	.33
Variance					
Variance of Estimate	17483.65	16.067.13	15429.29	15780.87	16522.47
Standard Error of Estimate	132.23	126.76	124.21	125.62	128.54
F-Test					
Degrees of Freedom	1,57	1,57	1,57	1,57	1,57
ANOVA for Prediction (F)	3.55	8.89	11.61	10.08	11.55
Probability (p)	.06	$< .01$	$< .01$	$< .01$	$< .01$

exposure an individual may be subjected to during an 8-hour shift. Several factors may have contributed to the high variance and low correlations found in these results. These factors include the nature of the job task, position of the microphone, sampling technique, and the validity of the 8-hour measurement.

The determination of the daily noise dose is a relatively straightforward procedure in situations where a worker is assumed to routinely perform the same repetitive task consistently throughout each work day. In most industrial settings, however, the daily routine of the employee tends to vary both within and across each work shift to meet the needs of the employer and the operational parameters of the equipment or industrial environment. Changes in the worker's task routine, which could be in

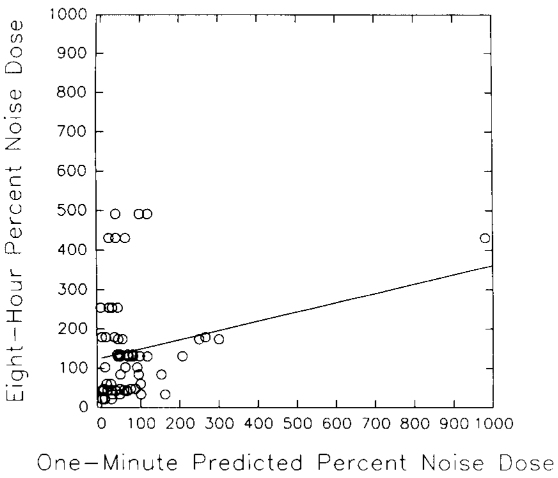

Figure 1 Scatterplot and line of best fit for the regression analysis of the 1-minute and 8-hour percentage noise dose measurements.

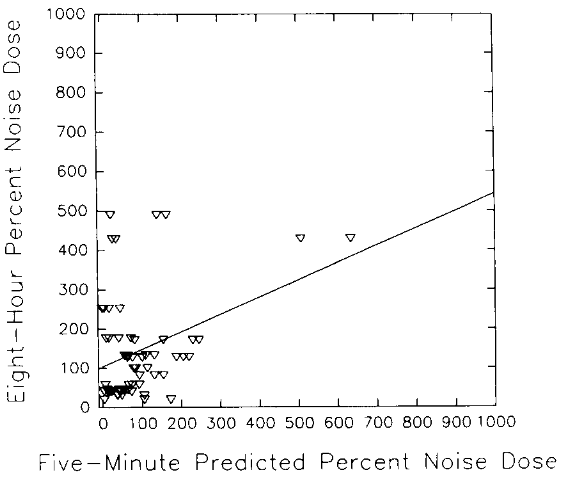

Figure 2 Scatterplot and line of best fit for the regression analysis of the 5-minute and 8-hour percentage noise dose measurements.

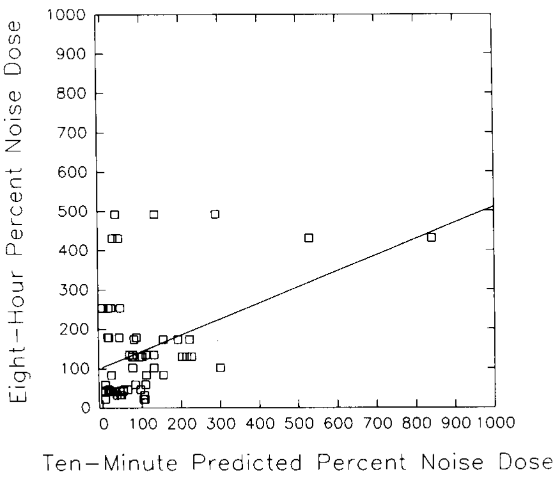

Figure 3 Scatterplot and line of best fit for the regression analysis of the 10-minute and 8-hour percentage noise dose measurements.

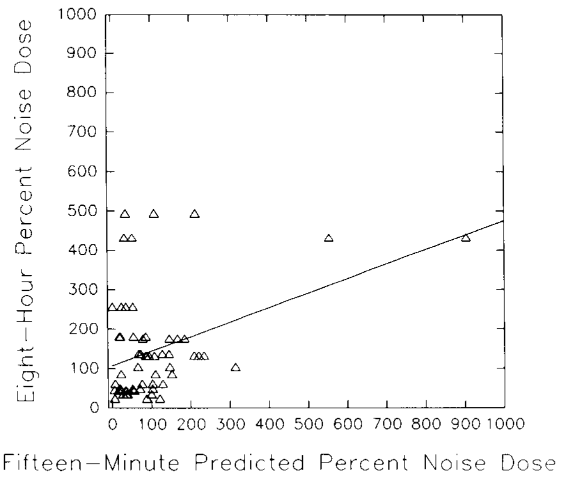

Figure 4 Scatterplot and line of best fit for the regression analysis of the 15-minute and 8-hour percentage noise dose measurements.

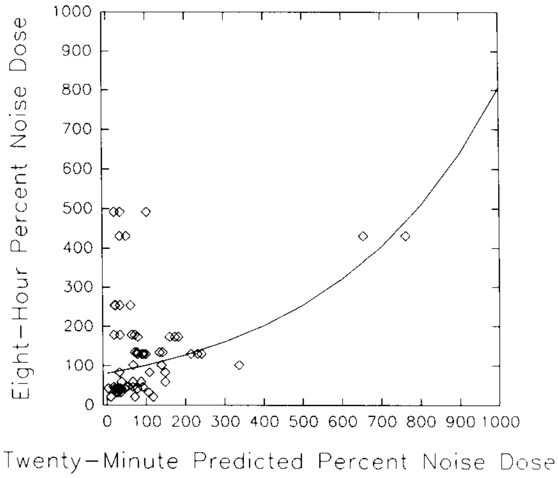

Figure 5 Scatterplot and line of best fit for the regression analysis of the 20-minute and 8-hour percentage noise dose measurements.

response to product or machinery variables, may cause changes in the daily noise dose. Most modern industrial operations are relatively automated and, as a result, most workers are not required to be in constant contact with the equipment. Rather than operating equipment, many workers serve to monitor operations, replace consumable supplies, and perform routine or emergency maintenance activities. Given that there are dynamic changes that occur in the industrial work area and that employees are no longer working on the same repetitive task in a static environment, the worker may not be exposed to a steady consistent noise level throughout his/her shift. Instead, the worker may be exposed to noise that is constantly changing in its frequency, intensity, and temporal parameters. Therefore, brief sampling techniques may not accurately predict the 8-hour dosimetry measurement due to the significant variability between the sampled noise doses at any given time and the 8-hour measurement.

Microphone placement also may have contributed to the variability in the data obtained for this study. The microphone of a dosimeter is typically placed on top of the subject's shoulder, with the microphone oriented parallel to the axis of the body or at the left breast pocket with the microphone oriented at 90 degrees to the body axis (Teplitzley and Paolillo, 1984). This was the intended placement in this study. Unfortunately, several problems in the microphone placement were observed during the collection of the data. First, in many instances, the microphone did not stay in the most optimal position. On several occasions, the microphone attached to the 8-hour dosimeter was either covered (e.g., when the employees put on outerwear) or displaced (e.g., when outerwear was taken off). For those employees who had to work periodically in areas requiring protective clothing, the microphone placement was adapted to meet the need to prevent damage to the microphone while simultaneously collecting data. The distortion of a sound field close to an observer, particularly in a direct field or in a field where pure-tone components are present, is well documented in the literature. Several investigators have studied the effects of microphone location on the body in various acoustic environments and have found that unstable microphone placement can result in false negative or false positive results (Basch, 1972; Confer et al, 1972; Wilson, 1972; Muldoon, 1973). Thus, the microphone placement may have affected the variability of the 8-hour dosimetry data and may have played a role in the lower correlations across samples than those measurements wherein microphone placement can be controlled.

The sampling technique itself may account for the variability found in the sampled noise dose measurements and the 8-hour measurement. The noise dose prediction feature, which is optional on many dosimeters, utilizes a method that enables measurements to be made on cyclical operating machines. A dosimeter that utilizes the noise dose prediction feature has a counting mode that can be accelerated to produce a statistically valid reading in a short period of time. The accelerated mode produces large numbers in a short period of time, thus speeding up the measurement and decreasing the sample duration needed for noise dose measurement. Although decreasing the sample length may provide a more rapid means of collecting data, it can also provide less reliable and less valid measures of actual noise exposure. In many industrial settings, employees may be exposed to high noise levels for a brief duration periodically through their shift. If the sample was obtained only during a period of high noise exposure, then it would predict a higher than normal noise dose, whereas if the sample was obtained during a period of low noise exposure, then it would predict a lower than normal noise dose.

In social and behavioral research, the knowledge on the part of the subjects participating in an experiment may produce an effect in addition to that of the independent variable. Influences of this kind are grouped under the Hawthorne effect (Hedge, 1987). It may be possible that the large variances observed in the abbreviated duration sample data and in the 8-hour percentage noise dose measurements were influenced by the Hawthorne effect. Several informal observations made during this investigation suggest that this phenomenon was observed at all four industrial sites. At one site, an employee was observed completing a task that would have otherwise taken him 30 minutes within the 20-minute sample time. At another site, an employee was observed to increase his productivity during the abbreviated noise dose sampling compared to when a sample was not being taken. Whereas the experiment focused on the noise levels themselves, the noise level may have been correlated to the activities or productivity of the employee. During the abbreviated measurements, employees were observed to be at their peak productivity. Although the employees were reminded to perform their tasks as they would normally, an increase in the productivity rate was observed whenever the abbreviated noise dose measurements were sampled and, as a result, the workers' activities may have biased these samples.

Given the high variance in the measurements obtained in this study, questions arise concerning the validity and reliability of 8-hour dosimetry. In many cases, it is unknown whether dosimetry measurements are reliable because the measurements are rarely, if at all, repeated. The Canadian government has adopted a standard for the measurement of occupational noise exposure (Canadian Standards Association, Z107.56 Procedures for Measurement of Occupational Noise Exposure), which requires a minimum of two readings. If the two readings fall within 2 dB of each other, their mean is used as the noise dose measurement. If not, the measurements are repeated until their standard deviations are within 3 dB (Kelsall and Behar, 1988). In the United States, the ANSI Working Group S1-3 (Melnick, 1987) is currently charged with developing standard specifications for integrating sound level meters. Timing specifications, specifications and tolerances of integrating and squaring networks, range of signal levels and durations to be measured, accuracy of these measures, and calibration of the devices are just a few of the issues that must be resolved by this working group. In addition, ANSI Group S1-7 is charged with developing and revising standards for personal dosimeters. At this time, their revision of the existing standard places greater emphasis on the response of the dosimeters to electromagnetic and radio frequency interference, on the decisions about measurement of impulses, on the range of noise bands to be tested, and on strengthening the specifications for lower noise limits to be included in the measure of exposures. Until studies have validated the 8-hour measurements, it is unknown whether dosimetry can accurately reflect a worker's noise exposure dose. Wilkerson (1975) noted that dosimeters generally met the applicable sections of ANSI S1.4-1971, but that dosimeter indications and exposures calculated from sound level meter readings could vary widely, even though the instruments comply with existing standards. The variability in the data obtained in this study is consistent with Wilkerson's observation and it appears, then, that the reliability, validity, and accuracy of dosimetry measurements need further examination.

Lipscomb (1988b) indicated that when sound levels at a work station were sampled for 60 seconds repeatedly throughout a work shift, it was common to find that the averaged measures did not vary more than 1 or 2 dB. Although this observation may be true for a work station, the actual levels of noise in the immediate vicinity of employees appear to vary widely across and within subjects. The sampled noise doses did not correlate with the overall 8-hour measurements in this study, regardless of the duration or the frequency of the sampling. The mobility of the worker, the dynamic changes in the industrial environment, and the work behavior of the employee all contributed to the unreliability of the sampled noise measurements as a dependable predictor of noise exposure.

The problems associated with noise dosimetry measurements were greater than expected in this study. Given the poor predictive value of short-duration (1–20 minutes) sampled noise dose data to 8-hour dosimetry, the application of dosimetry itself may be questionable. Specifically, are measures obtained by 8-hour dosimetry reliable and valid? These reliability and validity issues will have direct impact on any dosimetry measurement techniques used in practice or in research. The Canadian Standards Association requires a minimum of two readings (Kelsall and Behar, 1988). If the validity of 8-hour dosimetry is verified, then determining the utility of predicted noise measurements would be less complicated. Studies have shown that the duration of the noise level that is a critical variable for determining the risk of noise-induced hearing loss is hard to establish, even with dosimetry (Nilsson et al, 1976). Without a thorough knowledge of the conditions of the industrial site being measured, combined with information of how the noise levels interact within the test environment, the reliability, validity, and accuracy of the dosimetry measurements may be questionable.

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REFERENCES

American National Standards Institute. (1971). *American National Standard Specifications for Sound Level Meters.* (ANSI S1.14-1971). New York: ANSI.

American National Standards Institute. (1977). *Criteria for Permissible Ambient Noise during Audiometric Testing.* (ANSI S3.6-1977). New York: ANSI.

American National Standards Institute. (1978). *American National Standard Specification for Personal Noise Dosimeters.* (ANSI S1.25-1978). New York: ANSI.

Basch MW. (1972). A wearable pocket noise dosimeter. *J Acoust Soc Am* 52:80–82.

Canadian Standards Assocation. (1988). *Procedures for Measurement of Occupational Noise Exposure.* (CSA Z107.56). Ottawa: CSA.

Cheremisinoff P, Ellerbusch F. (1982). *Guide for Industrial Noise Control.* Ann Arbor, MI: Ann Arbor Science Publisher.

Confer RG, Blacker TH, Brief RS. (1972). Evaluation of personal noise dosimeter. *Am Ind Hyg Assoc J* 23:767–774.

Feldman AS. (1985). Types of hearing conservation programs. In: Feldman A, Grimes CT, eds. *Hearing Conser-*

vation in Industry. Baltimore: Williams & Wilkins, 89–102.

Hedge MN. (1987). *Clinical Research in Communicative Disorders: Principles and Strategies.* Boston: College Hill Press.

Kansas Department of Publications. (1990). *Kansas Directory of Commerce.* Topeka, KS: Author.

Kelsall T, Behar A. (1988). New Canadian standard for the measurement of occupational noise exposure. *Noise Control Eng J* 4:181–185.

Lipscomb DM. (1988a). Basic principles of sound measurement. In: Lipscomb D, ed. *Hearing Conservation in Industry, Schools, and the Military.* Boston: College Hill Press, 35–44.

Lipscomb DM. (1988b).Determination of noise exposure. In: Lipscomb D, ed. *Hearing Conservation in Industry, Schools, and the Military.* Boston: College Hill Press, 35–44.

Melnick W. (1987). Noise standards for the work place. *Noise Control Eng J* 29:15.

Muldoon TL. (1973). Response vibrations of a microphone worn on the human body. *Bureau of Mines* R1-7810.

Nillsson R, Kihlman T, Liden G, Sanders A. (1976). Individual noise dosimetry. *Scand Audiol* 5:191–195.

Teplitzley AM, Paolillo AW. (1984). Engineering aspects of noise control. In: Miller MH, Silverman CA, eds. *Occupational Hearing Conservation.* Englewood Cliffs, NJ: 28–61.

Wilkerson R. (1975). Sound level meters and dosimeter response to unsteady noise levels. *Noise Control Eng J* 17:68–75.

Wilson RD. (1972). *Personal Noise Dosimeters.* Paper presented at the American Industrial Hygiene Association Conference, San Francisco, CA, May, 1972.