THE DISTRIBUTION OF CONTAMINANTS IN THE INDOOR OFFICE ENVIRONMENT

W. Karl Sieber, Michael Barsan, National Institute for Occupational Safety and Health
W. Karl Sieber, 4676 Columbia Parkway, Cincinnati, Ohio 45226

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1. Introduction

Health symptoms experienced by workers are often assumed to be related to the presence of contaminants in the working environment. In order to understand the relationship between symptoms and exposure to contaminants, a knowledge of the concentrations of these contaminants and their distribution is necessary.

Typically occupational environmental data is assumed to follow a log-normal distribution. Conditions for log-normality may include: a) contaminant concentrations cover a wide range of values; b) a large proportion of the concentrations lie close to given value; c) differences between measured concentrations are of the magnitude of the measured concentrations; and d) there is a limited probability of very large values or data 'spikes' (Leidel et al. 1977).

Distributions other than the log-normal, most notably the gamma distribution, have also been considered for contaminant data and may be applicable under certain conditions (Berry and Day 1973; Eberhardt and Gilbert 1976). The applicability of the log-normal and gamma distributions to characterize contaminant concentrations measured in the indoor office environment was examined in this study using measured contaminant levels in an occupied office building and a recently renovated office building. The distribution most applicable to conditions in each building was determined.

2. Data Sources

Environmental investigations were done in 2 office buildings to characterize the indoor concentrations and spatial distribution of environmental contaminants in each building, and to evaluate the nature and spatial distribution of the employees' health symptoms and comfort concerns in each. Investigations in each building included air monitoring for respirable particulates (particles smaller than 2.5 μm) and total volatile organic compounds (TVOCs). Building 1 was a fully occupied building where indoor environmental quality complaints had previously been received and the investigation had been requested, while building 2 was a recently renovated building in the process of being occupied. Data was collected at various stages of occupancy of building 2. All investigations were conducted under the Health Hazard Evaluation (HHE) program of the National Institute for Occupational Safety and Health (NIOSH).

Although demographic and health information were collected from building employees, only air monitoring data was considered for this analysis. In order to minimize factors such as human activity and occupancy which might affect contaminant levels in each building, only data collected when both buildings were most fully occupied were considered. Log-normal and gamma distributions were fit to data collected in each building. The shape parameters from the gamma fits were tested using a likelihood ratio procedure to determine if they were significantly different from 0. Since the log-normal distribution is a special case of the gamma when the gamma shape parameter equals 0 (Lawless 1982), a shape parameter not significantly different from 0 would indicate that the log-normal distribution could best be used to characterize the data. In addition, plots of observed vs. predicted concentrations were developed for each building and distribution to determine which distribution best characterized the observed distribution of contaminants in that building. Predicted values were calculated using parameters estimated from the log-normal or gamma distribution fit. Comparison of the observed vs. predicted plots and the line Y=X may be used as a measure of how well the observed data is approximated by the log-normal or the gamma distribution. Deviations from linearity indicate deviations from the distribution in question.

All models were fit and tested using SAS PROC LIFEREG, and plots were generated using SAS PROC GPLOT.

3. RESULTS

Distribution parameters for respirable particulates in buildings 1 and 2 under both log-normal and gamma distributions are shown in Table 1. The gamma scale parameter is not significantly different from 0 in building 2, indicating that respirable particulates may best be characterized by a log-normal distribution in Building 2. The gamma shape parameter is statistically significant in building 1, indicating that the gamma distribution may be preferred there. It should be noted

that there is little difference between the intercept or scale parameters under either the log-normal or gamma distributions in building 2, while the scale parameters differ between distributions in building 1.This may indicate the importance of the gamma shape parameter in order to characterize the distribution of respirable particulates in building 1. Concentrations predicted under the gamma model in building 1, and the log-normal model in building 2, are shown in Figure. It can also be seen that the range of concentrations of respirable particulates are much less in building 1 than in building 2.

Distribution parameters for TVOCs under the log-normal and gamma distribution assumptions in buildings 1 and 2 are shown in Table 2. The shape parameters are not statistically significantly different from 0 in either building, indicating that the log-normal distribution may best characterize TVOCs in both buildings. Estimates of both the intercept and scale parameters under each distributional assumption are similar for each building. Predicted TVOC concentrations under the log-normal model are shown in Figure 2.

4. DISCUSSION

Either a gamma or log-normal distribution may be used to characterize the distribution of the indoor contaminants considered here. Both give consistent results for scale and shape parameters for a given investigation. These results might be expected since the log-normal is a special case of the gamma distribution with shape parameter 0. The gamma, because of its incorporation of both scale and shape parameters, is a more flexible, general-purpose model. Environmental contaminants may also possibly be characterized by additional distributions such as the Weibull or exponential distributions, which are additional special cases of the gamma with shape parameter 1 or scale parameter 1, respectively. However, the log-normal distribution occurs most frequently in environmental and occupational exposure applications, and is easy to use since its properties have been extensively investigated.

The shape parameter in the gamma fit is not significantly different from 0 for TVOC concentrations measured in buildings 1 or 2 or for respirable particulates in building 2. The 0 shape parameter indicates that TVOC concentrations appear to follow a log-normal distribution, while respirable particulates may follow either a log-normal or gamma distribution. It is possible that TVOCs follow a log-normal distribution more closely than respirable particulates. Another possibility is that the gamma is most applicable at low concentrations of contaminants.

REFERENCES

Berry G and N.E. Day (1973): The Statistical Analysis of the Results of Sampling an Environment for a Contaminant When Most Samples Contain an Undetectable Level. Am J of Epidemiol 97:160-166.

Cleveland WS (1993): Visualizing Data. Hobart Press, Summit, New Jersey.

Eberhardt LL, Gilbert RD, Hollister HL, and JM Thomas (1976): Sampling for Contaminants in Ecological Systems. Env Science & Technology 10 (9):920-925.

Leidel NA, Busch KA, and JR Lynch (1977): Occupational Exposure Sampling Strategy Manual. U.S. Department of Health, Education, and Welfare DHEW (NIOSH) no. 77-173, January 1977.

SAS Institute, Inc. (1990) : SAS/STAT User's Guide, Release 6. SAS Institute, Cary, NC.

Lawless JF (1982):Statistical Models and Methods for Lifetime Data, John Wiley and Sons, New York.

Table 1. Distribution Parameters for Respirable Particulates

Parameter	Distribution	Building 1 Estimate	(S.E.)	Building 2 Estimate	(S.E.)
Intercept	Log-normal	-4.130	(.066)	-3.564	(.081)
	Gamma	-3.905	(.074)	-3.642	(.144)
Scale	Log-normal	.479	(.047)	1.125	(.057)
	Gamma	.342	(.043)	1.120	(.058)
Shape	Gamma	1.119	(.317)	- .139	(.213)*

*Not statistically significantly (i.e. p>.05).
S.E.=Standard Error

Table 2. Distribution Parameters for Total Volatile Organic Compounds (TVOCs)

Parameter	Distribution	Building 1 Estimate	(S.E.)	Building 2 Estimate	(S.E.)
Intercept	Log-normal	-7.517	(.126)	7.455	(.126)
	Gamma	-7.437	(.177)	7.569	(.223)
Scale	Log-normal	.641	(.089)	1.077	(.089)
	Gamma	.632	(.089)	1.066	(.091)
Shape	Gamma	- .219	(.399)*	- .214	(.344)*

*Not statistically significant (i.e. p>.05).
S.E.=Standard Error

Figure 1. Plot of Predicted and Observed Concentrations Of Respirable Particulates

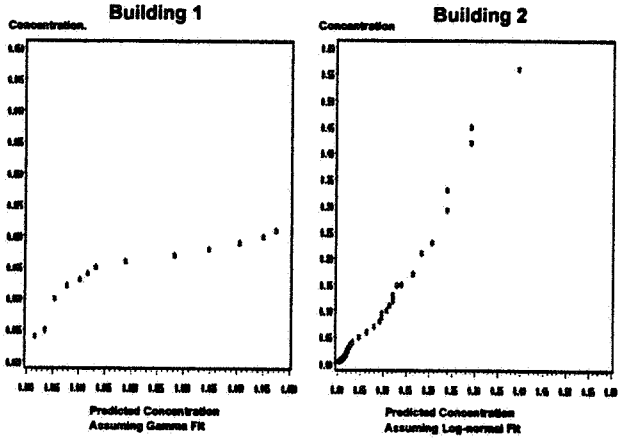

Figure 2. Plot of Predicted and Observed Concentrations of Total Volatile Organic Compounds (TVOCs)