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Title: CHEMICAL EXPOSURE ASSESSMENT PROGRAM AT LOS ALAMOS NATIONAL LABORATORY: A RISK BASED APPROACH

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The Chemical Exposure Assessment Program at Los Alamos National Laboratory: A Risk Based Approach

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The University of California Contract And DOE Order 5480.10 require that Los Alamos National Laboratory (LANL) perform health hazard assessments/inventories of all employee workplaces. In response to this LANL has developed the *Chemical Exposure Assessment Program.* This program provides a systematic risk-based approach to anticipation, recognition, evaluation and control of chemical workplace exposures. Program implementation focuses resources on exposures with the highest risks for causing adverse health effects. Implementation guidance includes procedures for basic characterization, qualitative risk assessment, quantitative validation, and recommendations and reevaluation. Each component of the program is described. It is shown how a systematic method of assessment improves documentation, retrieval, and use of generated exposure information.

INTRODUCTION

The Los Alamos National Laboratory (LANL) Chemical Exposure Assessment (CEA) Program provides a systematic, risk-based approach to the anticipation, recognition, evaluation, and control of chemical workplace exposures. The program's purpose is to ensure that employees are not adversely affected from exposure to chemical stressors in the workplace. A primary function of the program is to qualitatively assign risk to potential chemical workplace exposures. Validation of qualitative risk assignment is accomplished through sampling and monitoring. Because workplace exposures cannot be totally eliminated, this program strives to control hazards to an acceptable level and be an effective primary prevention tool against occupational injuries and illnesses.

DEFINITIONS

Exposure Group (EG)	A group consisting of an employee(s), job assignment(s)/task(s), and chemical stressor(s), such that exposure monitoring of one individual within the group is representative for all individuals within the same group.
Exposure Rating (ER)	A numerical value between 0 and 4 that represents the qualitative employee exposure risk to a chemical stressor. The exposure rating is based on the level of hazard control, the frequency and duration chemical use, and the ability of a chemical to become airborne.
Health Effects Rating(HR)	A numerical value between 0 and 4 that represents the severity of a chemical's health effect and/or its toxicity.
TWA	Time-Weighted Average: The time-weighted average exposure concentration for a normal 8-hour workday and a 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day without adverse health effects.
STEL	Short-Term Exposure Limit: A 15-minute TWA exposure which should not be exceeded at any time during a workday.
Ceiling Value	An exposure concentration which should not be exceeded during any part of the working exposure.

PROGRAM IMPLEMENTATION

The components of the LANL CEA Program (described in the following subsections) follow the AIHA strategy for occupational exposure assessment[1]. Figure I graphically illustrates the relationship of each component.

"Place Figure I here".

Basic Characterization

The first component in the LANL CEA process is basic characterization of the workplace, work force, and occupational chemical stressors. Workplace characterization highlights operations, activities, and areas with potential chemical exposure pathways. It provides information on process flow and process chemistry. Information is gathered on routine operating conditions (e.g., temperature, pressure, concentration), types of process equipment, types of process controls, and potential exposure considerations. Work force characterization involves gathering employee demographic information for an understanding of how employees interact with operations, processes, or tasks. Chemical stressors are characterized so that the industrial hygienist has sufficient information on frequency, duration, personal protective equipment, and controls to make informed qualitative decisions on exposure risk.

The outcome of Basic Characterization is a complete demographic inventory of employees, their job assignments/tasks, and the chemical stressors that they are exposed to. Exposure Groups (EGs) are formed using the information gathered during basic characterization.

Qualitative Risk Assessment (QRA)

QRA is performed on each chemical stressor. The purpose of QRA is to identify the degree of exposure risk posed by each chemical within an EG. The components of QRA are the Health Effects Rating, Frequency of Use Rating, Level of Control Rating, Dispersion Rating, and Exposure Rating[2]. It is important to note that decisions regarding the degree of exposure risk and its application to the CEA Program are often subjective and professional judgement by competent industrial hygienists is mandatory.

Health Effects Rating

All chemicals are given a Health Effects Rating (HR). The HR is a numerical value ranging from zero (low) to four (very high), and is used to define the toxicity or potency of target organ response to hazardous material exposure. The Health Effects Ratings used in the CEA Program are derived from the LANL program for chemical

labeling[2]. The HR provides a first cut evaluation of the degree of risk for an adverse health effect upon exposure to a chemical stressor. The objective is that if a chemical has a low risk of conveying an adverse health effect then less scrutiny should be placed on it. Thus, chemicals carrying an HR of 0 (zero) or 1 are documented and automatically assigned an Exposure Rating of 0 (zero). An exception to this occurs when professional judgement dictates that factors not adequately reflected in the HR (e.g. dose, oxygen deficiency, flammability, reproductive or mutagenic properties) produce an adverse exposure scenario. When this occurs chemical stressors remain in the QRA process for further exposure risk evaluation. Chemical stressors carrying an HR of 2, 3, or 4 automatically continue in the QRA process.

Frequency of Use Rating

The Frequency of Use Rating reflects the degree of workplace chemical use. Duration and other chemical use factors are taken into account and used with professional judgement to assign the appropriate Frequency of Use Rating. Table I is used to assign Frequency of Use Ratings. If a chemical is assigned a 2 or less it is assumed to have a low Frequency of Use Rating and thus carry a reduced risk for an adverse exposure. This qualitative assignment is documented and the chemical stressor is given an ER of zero. Again, professional judgement must be used to determine whether an adverse exposure could occur, even at low Frequency of Use Ratings. If so, the chemical remains in the QRA process for additional exposure evaluation. All chemical stressors carrying a Frequency of Use Rating greater than 2 continue in the QRA process.

"Place Table I here".

Level of Control Rating

The extent an exposure is prevented or reduced through the use of engineering controls, work practices, or personal protective equipment is evaluated with the Level of Control Rating. As shown in Table II administrative controls and personal protective equipment are not assumed to be adequate substitutes for engineering controls. Even so, professional judgement is used to adjust the Level of Control Rating when administrative and/or personal protective equipment is effectively used in association with engineering controls. All chemicals carrying a Level of Control Rating equal to 1 are documented and are given an ER of zero. Those chemicals having a Level of Control Rating greater than 1 continue in the QRA process.

"Place Table II here".

Dispersion Rating

The Dispersion Rating reflects the ability of a chemical to become airborne and available to the inhalation pathway in the work environment. Table III defines the criteria used to assign the dispersion rating for each chemical. All chemical stressors making it to this step in the QRA process are assigned a Dispersion Rating and are applied to the ER Matrix discussed below.

"Place Table III here".

Exposure Rating (ER)

An ER of 1 through 4 is assigned to those chemicals that have been applied to each step in the QRA process. The ER is a numerical representation of the degree of exposure risk to a chemical stressor. The ER is determined by use of equation (1) and its application with the ER matrix shown in Table IV.

$$F \times L \times D = Overall\ ER \qquad (1)$$

Where: F = Frequency of Use Rating
L = Level of Control Rating
D = Dispersion Rating

"Place Table IV here".

VALIDATION

A required follow up to QRA is quantitative validation of assigned ERs. Components of the validation process are described below.

Sampling

A sampling strategy is developed based on a chemical's exposure rating. Table V shows how a chemical's exposure rating dictates the number of annual samples required for quantitative validation. Exposure scenarios in LANL's research and development environment do not always allow for classical sampling strategies. Thus, professional judgement must be used to determine a practical approach.

"Place Table V here".

Monitoring

All monitoring and analytical methods is conducted in accordance with LANL policy and with NIOSH or OSHA sampling and analytical methods. When a NIOSH or OSHA sampling and analytical method is not available for a chemical, a chemist in the analytical laboratory is consulted for an alternative collection strategy.

Interpretation and Decision Making[2]

This component of the validation process provides statistical insight into the significance of the exposure measurements collected. It also shows the exposure decisions that can be made, and where informed conclusions can be drawn. For the purposes of this paper all exposure distributions are assumed to be lognormal.

Centering Value

A Centering value is used to measure the center of an exposure distribution. For lognormal exposure distributions the centering value used is the geometric mean.

Tolerance Level Value

The Tolerance Level Value is calculated to measure the variability in the exposure distribution. This statistical tool reflects the percent of the expected exposure values that are below a set level. For example, the 90% Tolerance Level Value is the exposure value at which 90% of the exposure opportunities are below. Thus, the calculated geometric 90% Tolerance Level Value is that exposure level at which 90% (i.e., 900 out of 1,000) exposure values are likely to be at or below.

$$Tol_{90} = GM \; x \; GSD^{1.28} \qquad (3)$$

Where:

Tol_{90}	=	90% Tolerance Level
GM	=	Geometric mean
GSD	=	Geometric standard deviation
1.28	=	Number of standard deviation units corresponding with the 90th percentile of the distribution

Confidence Level

The Confidence Level is a measure of the distribution of exposure values around the Centering Value. A 95% two-tailed Confidence Level is determined using the calculated standard errors of the exposure distribution.

$$SE = \frac{\log\ (GSD)}{\sqrt{n}} \qquad (4)$$

Where:

GSD = Geometric standard deviation of the distribution of exposure values;
n = Number of samples in the data set.

A 95% two-tailed Confidence Level is now calculated:

$$Lower\ Confidence\ Level = (GM)\ x\ (geometric\ SE)^{-1.96} \qquad (5)$$

$$Upper\ Confidence\ Level = (GM)\ x\ (geometric\ SE)^{1.96} \qquad (6)$$

Using the three statistical tools above, this discussion now answers the following question:

Q: What is the exposure level of an employee in an exposure group?
A: The Centering value provides an estimate of the most likely exposure level. The Tolerance Level Value and Confidence Level provide an estimate of how extreme the exposures can be.

Validation of Exposure Ratings

The qualitative Exposure Ratings can now be validated by application of the 90% tolerance limits to the appropriate exposure rating matrix shown in Tables VII & VIII. If an exposure rating is not validated then errors in the QRA process are investigated.

"Place Table VI here".

"Place Table VII here".

RECOMMENDATIONS AND REEVALUATION

Recommendations

LANL CEA Program recommendations are based on validation of a chemical's ER. An

exception exists when an imminent hazard is identified during basic characterization. In this case, a recommendation for increased control measures is made immediately, prior to assignment and validation of an ER. In general, typical program recommendations identify the need to alter existing control methods and the level of effort required for chemical sampling and monitoring. In a broader usage of LANL CEA Program information, recommendations are made to aid in the performance of reproductive health hazard assessments, carcinogen use hazard assessments, personal protective equipment hazard assessments, and determinations for the need of employee medical surveillance.

Reevaluation

It is the intent of the LANL CEA Program to perform reevaluations annually. This periodicity may be insufficient for some EGs and too frequent for others. Thus, there are three guidelines which are followed to determine the necessity of a reevaluation:

- Awareness by a field industrial hygienist of a change in an EGs status or scope.
- The presence of a highly dynamic EG. The more dynamic the EG the greater the periodicity of an exposure assessment.
- Three years have past without the performance of an exposure assessment.

LIMITATIONS

The LANL CEA Program is limited to evaluation of normal operating conditions. Off normal occurrences are more complex and beyond the scope of this paper. This program utilizes a single stressor model for exposure assessment. This means that an overall ER does is not calculated for simultaneous exposure to multiple chemicals. In the case of exposure to a mixture of chemicals having additive (similar toxicological effects) or independent effects the exposure is documented and a professional industrial hygienist uses the American Conference of Governmental Industrial Hygienist Threshold Limit Value (ACGIH-TLV) for mixtures to determine the level of compliance. Also, ERs applied to sensitized individuals may not adequately reflect their risk of an adverse response from a chemical exposure. During Basic Characterization, if a sensitizer is detected then the information is documented and a professional industrial hygienist determines the appropriate action to take to minimize the exposure to an acceptable level.

CONCLUSION

The LANL CEA program shows that chemical exposure assessment can be performed in a systematic fashion. Using a risk based approach aids in prioritizing time and resources to areas where they are needed most. The validation component of the

LANL CEA Program gives the industrial hygienist a template for determining the type and degree of exposure sampling required for a given EG. Through the use of computer automation CEA information can be rapidly shared among the many program stakeholders. Occupational medicine can use employee exposure information as a tool for primary prevention of injury and illnesses. Exposure Ratings can be used to justify the need for increased control measures to operational and line management. Regulators can be shown the risks of chemical exposure, where they are occurring, and what employees are receiving them.

It is this author's opinion that exposure assessment is not a new concept, but simply a systematic way to apply the fundamental principles of industrial hygiene. Too often, industrial hygiene programs are forced to operate in a reactive mode to satisfy the multitudinous needs of their customers at the expense of exposure assessment consistency and documentation.. This makes retrieval and historical use of such information elusive and difficult to decipher. A standardized approach, like the LANL CEA Program, addresses these problems and helps a proactive industrial hygiene program efficiently manage exposure assessment information.

References

1. N.C. Hawkins, S.K. Norwood, J.C. Rock, Eds., "A Strategy for Occupational Exposure Assessment", American Industrial Hygiene Association (1991).

2. Schinkel, Jeffery, "The MSDS Program at Los Alamos National Laboratory", Environment, Safety, and Health Division, Los Alamos National Laboratory (1993).

3. Stenzel, Mark, et al.
"Exposure Assessment Program", Office of Corporate Safety, Occidental Chemical Corporation (1993).

TABLE I
FREQUENCY RATING MATRIX

RATING	DESCRIPTION
1	Chemical is used less than once per month
2	Chemical is used at least one day per month
3	Chemical is used at least one day per week or has a STEL or ceiling value assigned to it
4	Chemical is used up to four hours per day
5	Chemical is used greater than four hours per day

TABLE II
LEVEL OF CONTROL RATING MATRIX

RATING	LEVEL OF CONTROL
1	Effective engineering controls (meets design specifications) in place to contain/remove airborne contaminants from the work area
2	Ineffective engineering controls (conditional or fails design specifications) in place; using PPE and administrative controls as primary method of minimizing worker exposure
3	No controls in place; visible airborne contaminants; odors or other sensory response indicates potential for exposure exists

TABLE III
DISPERSION RATING MATRIX

RATING	VAPOR PRESSURE (@ 20°C)	PARTICLE SIZE
1	Low (<50 mm Hg)	Nonrespirable (>25 μm)
2	Moderate (50 – 250 mm Hg)	Moderate (10 – 25 μm)
3	High (>250 mm Hg)	Respirable (<10 μm)

TABLE IV
EXPOSURE RATING

OVERALL ER	EXPOSURE RATING
<6	0
6 – 12	1
13 – 18	2
19 – 24	3
>24	4

Table V
Number of Required Annual Samples

Exposure Rating	# of annual samples
0	3 annual samples for 10 %
1	3
2	3
3	6
4	6

TABLE VI
EXPOSURE RATING VALIDATION
FOR TIME WEIGHTED AVERAGE EXPOSURES

EXPOSURE RATING	90% TOLERANCE LIMIT CONCENTRATION
0	≤ 10% OEL
1	11% to 25% OEL
2	26% to 50% OEL
3	51% to 99% OEL
4	≥ 100% OEL

TABLE VII
EXPOSURE RATING VALIDATION
FOR SHORT-TERM AND CEILING EXPOSURES

EXPOSURE RATING	90% TOLERANCE LIMIT CONCENTRATION
0	≤ 10% OEL
1	11% to 49% OEL
2	50% to 99% OEL
3	100% to 199% OEL
4	≥ 200% OEL