PRELIMINARY

"LEADERS IN PERFORMANCE"

EOCOM
CORPORATION

DETERMINING THE PLANT ENVIRONMENT AND EMPLOYEE EXPOSURES WITH THE EOCOM IDAAC SYSTEM

August 21, 1975

PRELIMINARY

DETERMINING THE PLANT ENVIRONMENT AND EMPLOYEE EXPOSURES WITH THE EOCOM IDAAC SYSTEM

August 21, 1975

EOCOM Corporation

TABLE OF CONTENTS

Section	Description
I	Introduction
II	Nature of Gas in the Work Environment
III	Sampling Algorithm
IV	Basic Reporting of the IDAAC System on the Plant Environment
V	Employee or Job Category TWA

TABLE OF FIGURES

Number	Description	Page
A	Small Number of Samples Per Eight (8) Hours	9
B	Many Samples Per Eight (8) Hours	9
C	Trend Response	10
1	Log Normal and Normal Distributions With the Same Arithmetic Mean and Standard Deviation	17
2	Multi-Layer Sampling	18

Determining the Plant Environment and Employee Exposures with the EOCOM IDAAC System

I Introduction

Over the past eighteen (18) months EOCOM has very carefully studied the concept of area monitors in conjunction with the following objectives:

- Fast Excursion Detection
- Accurate Employee TWA's
- Eliminate Requirements for Personal Sampling
- Management Information System to Aid in Achieving OSHA "Performance" Standards

After a thorough study, it was decided to embark on a measurement program to find out the in-plant variables involved in trying to achieve the objectives. In order to do this we then proceeded to:

- Quantify the Nature of Gases in the Work Environment
- Determine Appropriate Sampling Sequence for an Area Monitoring System
- Relate the Employees to the results of the Area Monitor and determine Their Exposure

II Nature of Gas in the Work Environment

In order to understand the work environment and how this relates to employee exposure, we have taken literally millions of samplespoint data from our various field installations and analyzed the data for the statistical nature of the gases in the breathing zone. The purposes of this effort was to establish the distribution of the gas concentration levels. This obviously is effected by the air flow,

molecular weight of the gas, reactivity of the gas in the atmosphere, type of source of the gas, etc. However, from these studies we have sufficient data to say that a "log normal" distribution is sufficient to represent the distribution of the gases studied in the various plants studied. To our knowledge this is the first in-plant data to confirm the NIOSH report of April, 1975 entitled "Statistical Methods for the Determination of Non-compliance with Occupational Health Standards", by Nelson A. Leidel and Kenneth H. Busch, HEW Publication No. (NIOSH) 75-159 (Reference 1). In this report they use air pollution data to support their "log normal" distribution methods. Now with our confirmation of this data (to be published in the latter half of 1975) (Reference 2), it is possible to use many of their analytical techniques and statistics. These can be used to analyze data from an area monitor to determine compliance (at various confidence levels), to predict plant performance based on the "log normal" statistical model and to easily analyze current plant performance against past plant performance for detection of significant trends.

More specifically the attached Figure 1 shows the difference between the "log normal" distribution and the more commonly used normal distribution. To define the "log normal" distribution it is only necessary to determine the Geometric Mean (GM) and the Geometric Standard Deviation (GSD) (similar to the Arithmetic Mean (μ) and Standard Deviation (ε) for the normal distribution).

$$GM = \mu \Big/ \sqrt{\varepsilon \frac{\ln \sigma}{\ln \mu} + 1}$$

$$GSD = \varepsilon \sqrt{\ln \left[\varepsilon \frac{\ln \sigma}{\ln \mu} + 1 \right]}$$

UCC
034149

EOCOM CORPORATION

The GM and GSD (for any time period long with respect to plant variations), completely defines, from a statistical viewpoint, the "log normal" curve for the frequency of concentration of various levels of the gas being monitored.

That is to say that you now have a definition of your plant environment that allows projection of the probabilities of various occurrences in the plant as well as to determine compliance with various OSHA "Performance" Standards. Thus, the EOCOM data system, as appropriate, calculated these parameters as well as TWA's.

III Sampling Algorithm

Given that the EOCOM data system keeps track of the GM and GSD of each breathing zone sensor probe* (of the area monitor), it is then possible to evolve a sampling algorithm that will have:

- Higher Probability of Excursion Detection
- Turn Warning Systems Off in the Shortest Time to Minimize the Use of Masks
- Isolate the Actual Probe Nearest the Cause for the Excursion

A. Probe Data

First using just the sample probe data (employee time/motion studies will be considered later), management selects a parameter(s)

* NOTE: For this discussion, no consideration is given to the number of samples from a probe that yield a useful GM and GSD. Also the effect of high instrument noise (not "log normal" distributed) relative to the variations in plant levels is not considered in this discussion. Both these parameters are a function of the area monitor used with the data system and should be evaluated on an individual case basis and could effect the distribution or time intervals used with the statistics.

(P [M]) of the gas that is key to their plant operation under the OSHA Standard. For instance in the case of the VCM Standard, management might select individual probe readings of greater than 25ppm until April 1, 1976, and 5ppm after that time with the objective of having the correct mask on at all the required times. On the otherhand, depending on the general levels of VCM in the plant, management might select eight (8) hour averages of the probes that are higher than 0.5ppm and 1.0ppm as two (2) parameters to determine the sampling algorithm. Another parameter that could be selected is the GSD of a probe. In any case the selection of the desired parameter (one or more) is made by management as a function of plant conditions relative to the standard as well as any other requirements they may have. For instance, let's take the case of selecting the probability of the sample probe having a reading of 5ppm or greater P [> 5ppm/reading]. Using the GM and GSD for each probe, the axis plural for the "log normal" distribution of Figure 1 is determined and a set of probabilities, one for each probe, is determined.

$P\ [M],\ P_2\ [M],.....P_n\ [M]$

These probabilities of probe readings at or above 5ppm are then used to determine those probes that should be sampled more often (i.e. higher P [M]) and from these probabilities is developed the sampling pattern where the sample probe selection is under the control of the EOCOM IDAAC System. The result being that those points with most likelihood of a 5ppm excursion are monitored more often.

B. Employee Data

A second level of effort is to also include as part of the sampling probability model, the probability of any employee being at any one

breathing zone probe. This data is derived from time/motion studies of the involved employees (or job categories).

From the time/motion study, one obtains the probability of each employee (category) with respect to probes.

$P [TA_1], P [TA_2].....P [TA_n]$

$P [TZ_1], P [TZ_2].....P [TZ_n]$

By combining the probabilities of all the employees (categories) with the P [M] for each point, you then have the probability for that probe that <u>any</u> employee may be exposed at that probe.

$P [E_1], P [E_2].....P [E_n]$

These probabilities are then used to generate a sampling distribution that is used in the sampling algorithm of the EOCOM IDAAC System.

C. <u>Search Sampling</u>

In addition to the above statistically controlled sampling, the IDAAC System also goes into a search routine when an initial alarm or excursion occurs. This search is performed to be sure that the highest point of concentration is located so that effective corrective action can be taken as soon as possible. This search routine takes into account the wind direction (normally known because of forced ventilation) as well as the probabilities of the points around the initial excursion. After establishing all of the alarm conditions in the area, the IDAAC System then proceeds

to monitor the rest of the system while establishing a higher priority for reading the alarmed area more often until the condition is corrected. Again all of the TWA (P)'s are calculated correctly by the trapezoidal integration.

D. Multi-Level Sampling

The IDAAC System also has the capability of multi-level sampling. The multi-level sampling concept is to monitor the mixture of several points simultaneously. That is to take for instance, 3 points and mix them in the gas manifold. Thus the measurement of the three (3) points would provide the average of the three (3) points (1, 2, and 3). In order to make a decision on a 5ppm alarm, the IDAAC analyzes the data as shown in Figure 2.

Multi-level sampling has the advantage of "sweeping" the plant at up to three (3) times faster than single point sampling. It has certain requirements to be effective and still not deteriorate the TWA and other calculations being performed by the IDAAC System.

1. In order to almost achieve the factor of 3 speed improvement the average levels in the plant (for the case of Figure 2) would have to be below 5/3 or 1.66ppm. In no case is the approach slower than single station sampling. The worst case is when all levels in the plant are 5ppm, then the system will measure R, R_1 and R_2, or three (3) measurements. Most cases we have observed are such that almost the full factor of three (3) can be achieved.

2. One has to take care in selecting the points that are to be averaged so as not to effect the other calculations. We

have shown that this is accomplished by selecting points with roughly equal P [E] and/or P [M]

3. Although the IDAAC System has the multi-level sampling capability, it may require different gas manifolding than presently in use.

In summary, the multi-level sampling capability does improve:

- Probability of Measuring Excursions
- Average Time To Survey the Plant

E. Summary of Sampling

In summary, the sampling algorithm of the IDAAC System allows the user to:

- Have a system that responds to its environment. Each day the GM and GSD are updated and the sampling algorithm corrected for plant trends and variations
- Sample the area monitor in an intelligent fashion based on the "living" statistical trends of the plant environment
- Select the sampling decision parameters that are deemed important to management
- Enter new or changed time/motion studies
- Get to excursions significantly faster than a sequential sample system
- Correct excursions fast

IV Basic Reporting of the IDAAC System on the Plant Environment

In order to provide management with significant information concerning the plant environment, its changes and the degree of compliance with a standard; the IDAAC system reports several parameters regarding the plant data measured by the probes. First, individual probe readings are available through the printer or by optional mass storage device. However, except for investigating specific events, it is felt that the following summary parameters are sufficient to fully define the environment for each probe.*

- TWA (P)
- Trend TWA: TWA (TP)
- GM (P)
- Trend GM: GM (TP)
- GSD (P)
- Trend GSD: GSD (TP)

The total plant (floor or area) environment is defined by the sum of the probe data for the plant (floor or area).

A) TWA (P): TWA (P) is calculated from the basic data points measured by the sensor probes. It is important to note that the non-uniform sampling (with time caused by the sampling theorem in section III above) requires careful attention to the means of calculating the TWA. The IDAAC system calculates the TWA with a trapezoidal integration of the individual readings, yielding the correct value for the area under the curve, which then for any given time period (15 minutes, 1 hour, 4 hours, 8 hours, etc.) provides the correct TWA (P).

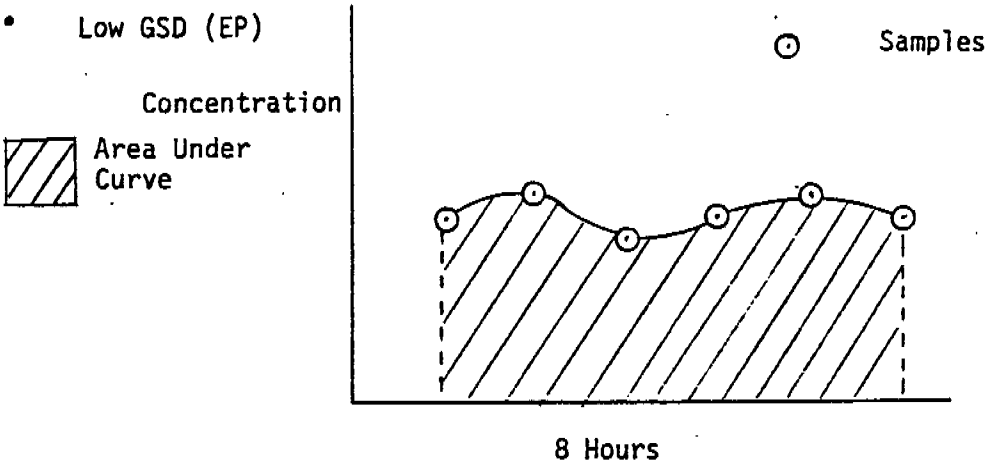
The area under the curve is shown in Figure A. It is this true area divided by the time that yields TWA values. It is interesting to note that most management selection criteria for P [M] will lead to an

* Note: The IDAAC System calculates many other parameters as noted in its specific specification sheet. The parameters discussed here are those used to describe the plant environment and employee exposure.

optimum sampling of the eight (8) hour period. That is to say that most of the selection criteria used by management will lead the sampling algorithm to sample active exposure areas more often than less active exposure areas. This is shown by the following conditions:

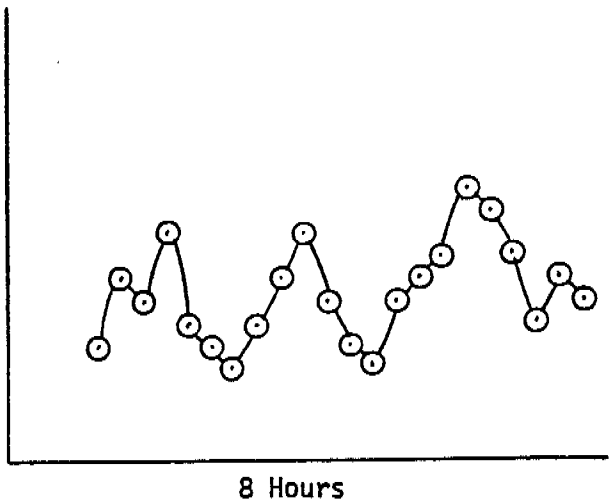
A) Small number of samples per eight (8) hours:

- Low P (M)
- Low P (E)
- Low GSD (EP)



B) Many samples per eight (8) hours:

- High P (M)
- High P (E)
- High GSD (TP)



EOCOM CORPORATION

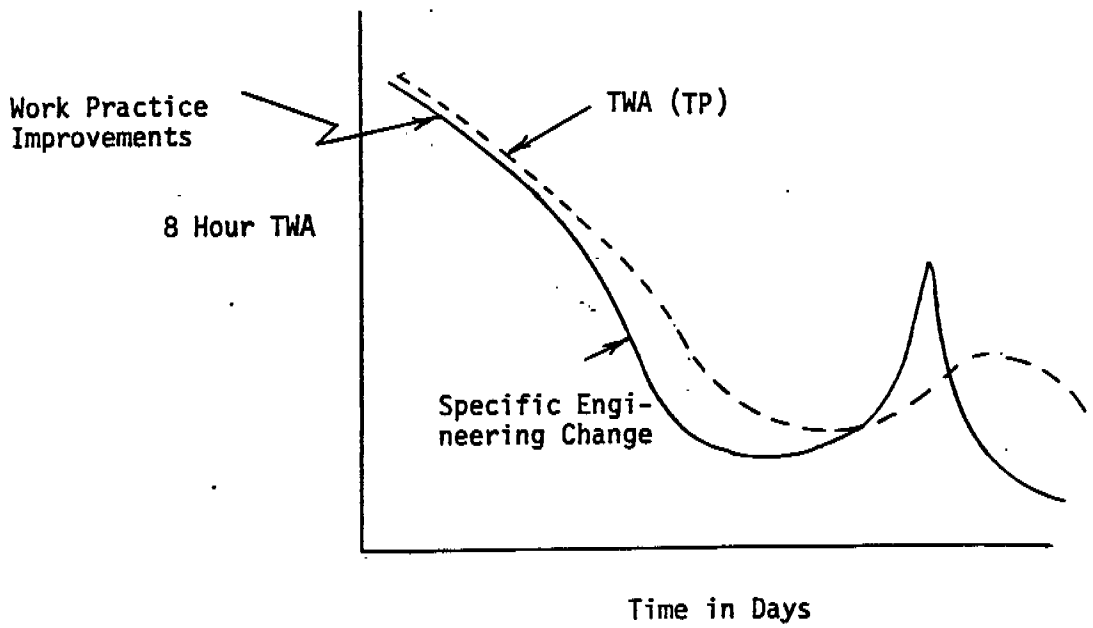
UCC
034156

In both cases the system samples the data correctly to provide the correct time weighted TWA (P).

C) Trend Responsive TWA (TP): In order to compare today's performance with past performance the IDAAC System outputs an exponential TWA which is:

$$TWA\ (TP)_0 = 0.X\ TWA\ (P)_0 + (\ 1 - 0.X)\ TWA\ (TP)_Y$$

Where the subscript 0 indicates today's data and the subscript Y indicates yesterday's data. The factor X determines the number of days that are used to determine the trend TWA (TP). The factor X is selectable by the user and can be varied to give very long term trends or shorter term (such as a week) trends. The effect of setting X to a time constant of seven (7) to ten (10) days is to smooth out any abnormalities of a given day, while at the same time giving data on the most recent performance of the plant. This is depicted in the following figure:

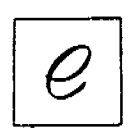


By this method you can readily compare today's performance TWA (TP) with the average of a previous (selectable) set of days and decide if today's performance is significantly different. An alternate path is to simply calculate the TWA for extended periods of time (rather than exponentially). This is possible with the system, however, it is our opinion that the most recent data contains more management significance, however, either is available from the IDAAC System.

D) GM and GSD:

The significance of GM and GSD is that they allow one to completely describe the plant in terms of statistical numbers. This uniquely defines the log normal curve in Figure 1 from HEW Document No. (NIOSH) 75-159, (Reference 1). Again it is significant to compare the present to the most recent plant data. By using this data, you can easily assess the plant performance for the day both in actual levels and in variations. Since it has been shown that the data is log-normal distributed it is also possible to use the GSD and GM from a series of days to project the plant environment into the next shift or day with a confidence level attached to projected performance on a future shift or day. Again, the continuing GSD and GM are reported as trends also. Thus the system reports: GM (P), GM (TP), GSD (P) and GSD (TP) in the same fashion as the TWA (P) and TWA (TP) values.

Further, using the GM and GSD allows one to assess whether any given shift or period is within the previous experience and whether a combination of shifts represents a new trend. Depending on the process and results from the system it may be more appropriate to keep separate records on the shifts in each day rather than running the average from shift to shift through the day into the next. In certain industrial cases we have noted a substantial difference in the value of GM and GSD from shift to shift. In one case, the night shift runs significantly higher than the other two shifts.



It is worthwhile to comment on the effect of the sampling algorithm on the calculation of GM and GSD for the eight (8) hour periods. The actual log normal distributions are based on random samples. The samples taken (at least for a short period) cannot be considered random, however, our data to date does show a substantially log normal distribution for periods as short as one hour.

V Employee or Job Category TWA

The IDAAC System calculates employee (or job category) exposure by using the measured TWA (P) for the time period of interest for each point and the time/motion study data ($P\ [T_{A_1}]$.....$P\ [T_{A_n}]$)

This approach leads to extremely good long term TWA of employees. Certainly it is based on more information than a 1 or 2 time/month personal sample. The time that the IDAAC System takes to converge on accurate TWA (when compared to charcoal tubes) is a function of many variables, such as:

- Conditional exposures
- Validity of time/motion study and its variability
- Placing of the sensors in the breathing zone
- Number of samples per measurement period provided by the area monitor
- Cyclic (or non-cyclic) nature of the process
- etc.

It has been our experience to date with an installed VCM monitor system that with the inclusion of the conditional exposure (man in reactor) that calculated TWA values converge to the measured TWA values in less than eight (8) hours.

For those situations where the employee may perform several job categories within a shift or from shift to shift, the job category concept should be used and the employee should log in on a per shift basis the time spent in each job category that is a regulated job category.

EPA Requirements

With the present proposed standards for EPA monitoring of plant effluents for substances such as VCM (EPA 40 CFR Part 61: National Emission Standards for Hazardous Air Pollutants Proposed Standard for Vinyl Chloride) EOCOM intends to offer an optional accessory to IDAAC System to perform either a mass calculation of VCM in the air in the plant and that VCM that escapes the plant into the environment or to accept data from an exhaust sensor (one or more) and provide the appropriate data analysis, such as 10ppm per hour limit. In view of the status of this proposed EPA VCM standard we have not chosen the final approach.

Effect on Employees

A true interactive intelligent monitor, as installed in a VCM monitoring situation, has been observed to have the following effects:

1. Excursions due to work practice have significantly decreased through to the speed of the monitor and its ability to capture 94% of the excursions. This has, without intervention of management, brought a force to bear on the employees which had the effect of dramatically reducing excursions due to work practices.

2. A previous monitor system was circumvented by the employees knowing the sequential nature of the sampling device. Knowing this they were able to perform critical operations that might cause excursions while the monitor is not sampling in the area. With installation of the new system and its sampling algorithm this was no longer possible and a significant change in work practices occur, which also improved productivety.

Nomenclature

GM : Geometric Mean

GSD : Geometric Standard Deviation

P [M] : Management Selected parameter for determining sampling algorithm (one or more can be selected)

P [T_{A_1}] : Probability of man A being at point 1, etc.

P [E] : Probability of exposing any employee at a sensor probe

TWA : Time weighted average as defined in 29 CFR 1910.93 (d) (1)

TWA (C) : Measured eight (8) hour time weighted average of an employee or job category

TWA (P) : Eight (8) hour time weighted average of a sensor probe

TWA (TP) : Exponential average of eight (8) hour time weighted average of a sensor probe

GM (P) : Eight (8) hour geometric mean of a sensor probe

GM (TP) : Exponential average of eight (8) hour geometric mean of a of a sensor probe

GSD (P) : Eight (8) hour GSD of a sensor probe

GSD (TP) : Exponential average of an eight (8) hour GSD of a sensor probe

Subscripts

1, 2, 3, n...: Probe numbers

A, B, C.....: Employee or Job Category

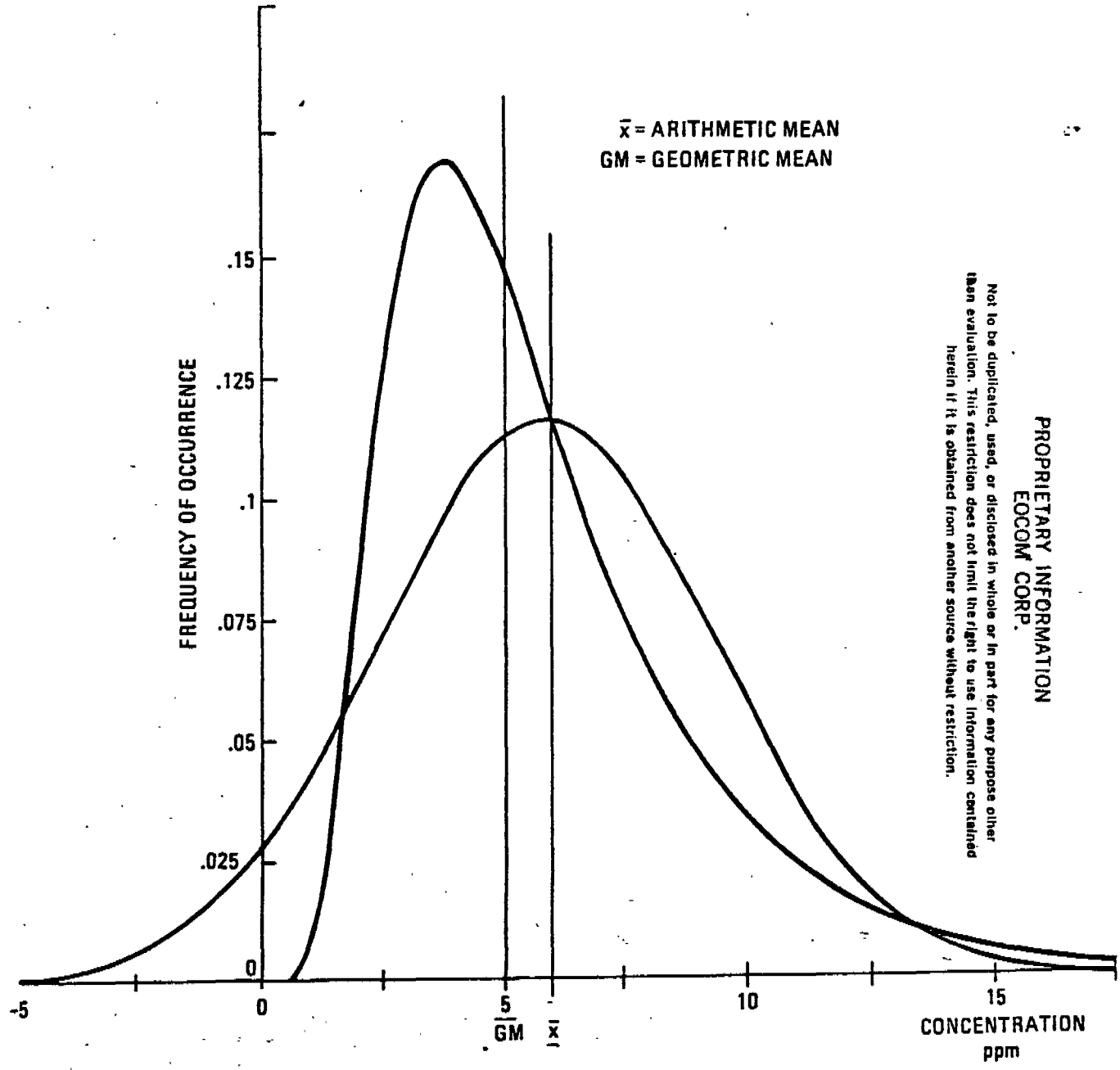


Figure 1 - Log normal and normal distributions with the same arithmetic mean and standard deviation.

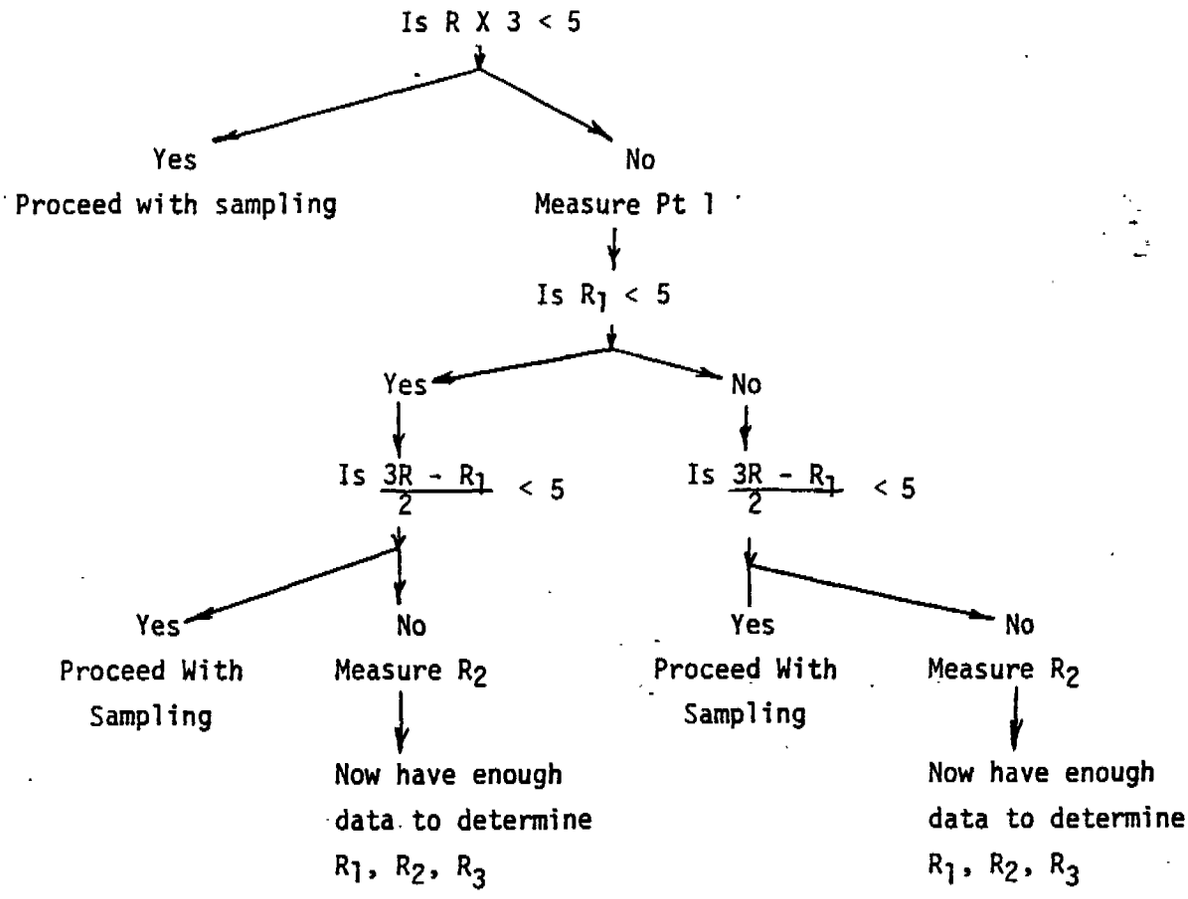
FROM: HEW Document No. (NIOSH) 75-159

"Statistical Methods for the Determination of Noncompliance Occupational Health Standards"

Situation

1. P [M] 5ppm
2. Simplified version of program.
   Note real program takes into account recent measurements of points and probability of most likely point of excursion.

Reading = R (Average of Points 1, 2 and 3)



Multi-Layer Sampling

Figure 2

EOCOM CORPORATION

UCC
034165

References

Reference One

HEW Publication No. (NIOSH) 75-159
"Statistical Methods for the Determination of Noncompliance with Occupational Health Standards"

Reference Two

"The Use of Area Monitors for Determination of Compliance with OSHA "Performance" Standards" by Joe Coppola, David Mattson, Ken Lindelin and Dr. S. Thomas Dunn (To be published)