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Workplace atmospheres - Scientific basis to describe the influence of the reference period on the presentation of exposure data

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Central Secretariat: rue de Stassart, 36 B-1050 Brussels

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Workplace atmospheres — Scientific basis to describe the influence of the reference period on the presentation of exposure data

Foreword

The aim of this document is to draw the attention on the issue of the reference period of anyone who generates, uses or interprets exposure data.

It does not deal with a strategy to assess compliance with limit values.

1 Introduction to the problem

Most occupational exposure limits are expressed as a concentration with the reference period of eight hours (shift duration or a normal working day).

There are some exceptions: the EU the directive on vinyl chloride contains a limit value over one year. In Germany the reference period for dust (respirable dust) and the long term special threshold values for quartz in respirable dust is also averaged over one year.

The following shortcomings of long-term limit values in exposure determination can be quoted:

- insufficient consideration of changing exposure conditions (day to day variability);
- availability of exhaustive exposure assessments only in the long run;
- difficulties in planning exposure-specific preventive action.

Harmonisation of the measurement duration makes it necessary to convert existing long-term limit values, derived from epidemiological findings, into short-term limits, i.e. limit values for a sampling time not exceeding one shift.

Hereinafter several approaches will be presented which vary according to the knowledge available for the exposure related to certain activities or branches.

2 Description of the process of establishing occupational exposure limits (which normally have the reference period of a normal working day)

The limit value is fixed using epidemiological data, extrapolation of animal experiments or by analogy with the limit value of comparable compounds.

In actual practice, limit values (with a reference period of eighth hours) are fixed at the numerical value of the threshold for a long term effect and only excursions above the numerical value of the limit value during a working day are allowed, provided the time weighted average for that day is not exceeded.

Normally, legally binding limit values are fixed by taking socio-economic and technological feasibility into account.

3 Distribution of measurement values — Parameters describing the distribution of measurement values

In epidemiological studies, doses are very often described by the determination of the arithmetic mean of the measurement values of concentration in the air which is breathed during the whole period of work, or the concept of the cumulative dose is used. Normally this dose is calculated by multiplying the arithmetic mean of the exposures of different activities (linked with different concentrations) with the total duration of exposure (during a particular activity).

Frequency distributions of the measurement values of chemical agents in the breathing zone in workplaces are best described by log-normal distributions. This corresponds to say that the logarithm of the concentration follows a normal distribution.

The parameters to define the normal distribution are μ for the arithmetic mean and σ for the standard deviation. The parameters to define a log-normal distribution are GM (geometric mean) and GSD (geometric standard deviation). μ, σ and GM have the dimension of the concentration, GSD has no dimension.

It is possible to estimate the parameters of both (related) distributions starting from one set of parameters (e.g. table m-1 of the NIOSH Occupational Exposure Sampling Strategy Manual).

4 Relation between short-term and long-term measurement values

Two steps are necessary to derive branch- or activity-related short-term concentrations from long-term limits.

What we need first is a theoretical, mathematical derivation resulting in a general conversion formula. Secondly, information must be available on the factual distribution of measurement results for the activity or branch under consideration. Finally, the geometric standard deviation must be known.

4.1 General mathematical approach

Measurement data obtained on an eight-hour basis for the branch- or activity-related exposure over a year are supposed to be known. The frequency distribution of these values is a log-normal distribution which can be described by the parameters GM and GSD.

A percentile (C_p) of this lognormal distribution can be described using the formula:

$$C_p = GM \times GSD^u \qquad (1)$$

where

Cp is P percentile;
GM is the geometric mean;
GSD is the geometric standard deviation;
u is the corresponding percentile of the standard normal distribution n (0,1), e.g. u = 1,65 for $P_{0,95}$.

Other values of u can be found in the normal distribution table.

In epidemiological studies average concentrations are generally calculated as the arithmetic mean of the measurement results.

According to Rappaport (1991), the ratio of the arithmetic mean to the geometric mean can be estimated as follows:

$$AM = GM \times GSD^{1/2 \ln(GSD)} \quad (2)$$

where:

AM is the arithmetic mean of the measured concentrations;

GM is the geometric mean of the measured concentrations;

GSD is the geometric standard deviation of the measured concentrations..

If, in an epidemiological study, a limit value was defined in terms of a year and calculated as an arithmetic mean, and if this limit value is to be redefined in terms of a shift, the shift-related measurement results create a log-normal distribution, as described above. The log-normal distribution indicates the probability of reaching or remaining below a certain value if only one measurement a year was carried out for the activity under consideration. In actual fact, the measurement result may coincide with any value of the log-normal distribution, so that from a theoretical point of view any percentile could be used for conversion into short-term limit values. As this makes calculation too difficult, the 95th percentile was agreed by convention.

The excursion factor is obtained using the following formula:

$$K_{AM} = \frac{Cp}{AM} = GSD^{u-0,5\ln(GSD)} \quad (3)$$

where

K_{AM} is the factor for conversion of the arithmetic long-term mean into a shift-related mean, $AM \times K_{AM} = C_p$.

4.2 Information on the geometric standard deviation, measurement results from the field

In the following tables measurement results are indicated along with the corresponding geometric standard deviations; they are summarised for branches or specific activities.

Table 1 —.Characteristic distribution of respirable dust measurements (alveolar fraction) in the coal mining industry (P = 97.5 %)

Field of study	No of measurements	GSD	K_{AM} (acc. to Fo.3)	K_{AM} (empirical)
coal mine A	12027	1.98	3.0	2.5
coal mine B	12408	2.21	3.5	4.1
coal mine C	29517	2.71	4.3	3.7

Table 2 — Characteristic distribution of respirable quartz dust measurements (alveolar fraction) in the coal mining industry (P = 97.5 %)

Field of study	No of measurements	GSD	K_{AM} (acc. to Fo.3)	K_{AM} (empirical)
coal mine A	11924	2.47	3.9	4.8
coal mine B	12341	2.71	4.3	6.9
coal mine C	21310	2.86	4.5	5.0

Table 3 — Characteristic distribution of respirable dust measurements (alveolar fraction) according to BIA-documentation MEGA (P = 97.5 %)

Branch of industry	No of measurements	GSD	K_{AM} (acc. to Fo.3)	K_{AM} (empirical)
plastics	3664	2.6	4.1	5.2
steel, mech. eng.	2459	2.6	4.1	5.7
electronics	1048	2.8	4.4	4.5
timber, printing	795	2.8	4.4	5.2
metal	10971	2.9	4.5	3.0
quarrying	6562	3.0	4.7	4.0
construction	815	3.1	4.9	5.9
mining	611	3.6	5.4	4.0
chemical industry	1851	3.6	5.4	4.1

Table 4 — Characteristic distribution of respirable quartz dust measurements (alveolar fraction) according to BIA-documentation MEGA (P = 97.5 %)

Branch of industry	No of measurements	GSD	K_{AM} (acc. to Fo. 3)	K_{AM} (empirical)
gallery driving, tunnel construction, shaft lining, throughpressing	343	3.4	5.2	6.6
chemical industry	255	4.9	6.4	6.8
stone working	850	4.1	5.9	4.0
(floor) tiles, Dutch tiles, architecturally applied ceramics, manufacturing	247	2.8	4.4	4.1
iron foundries	2762	2.7	4.2	4.2
metal working in general	387	2.1	3.3	10.3

It can be seen that the GSD values within a certain branch of industry vary between 2 and 5, while their normal variation is between 2.5 and 3. If additional information about a branch or specific activity is not available, a standard deviation of 2.7 can be assumed as a rule.

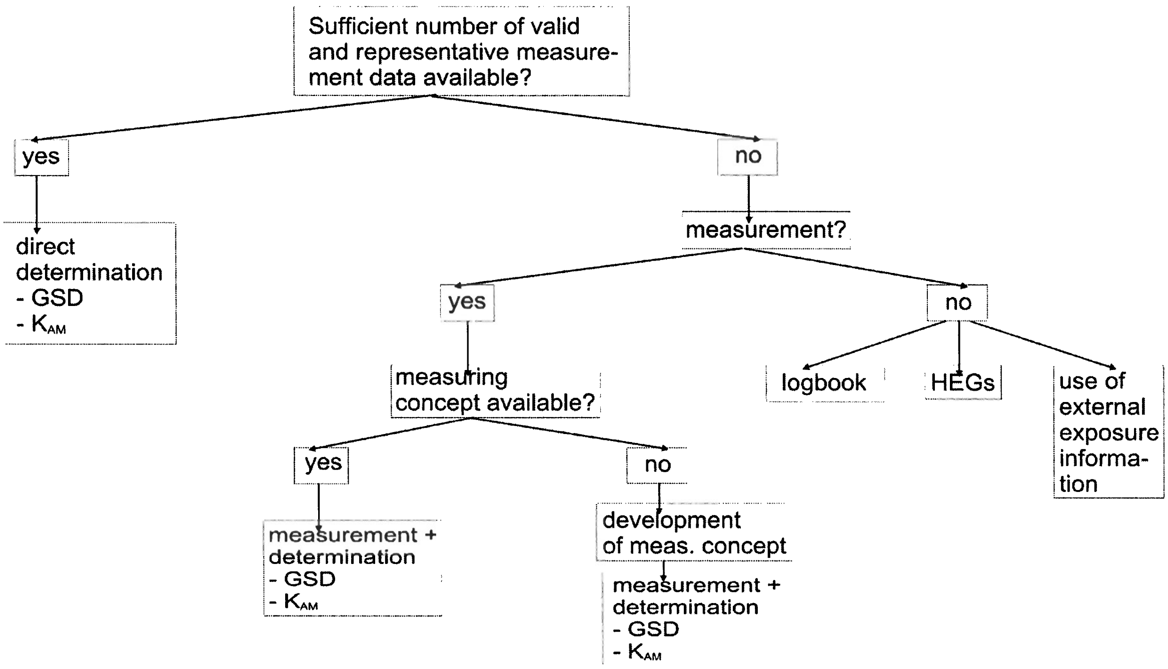
NOTE Some authors have described much higher GSD values, especially for gases and vapours).

From this, excursion factors (K_{AM}) in the range between K_{AM} = 2.5 and K_{AM} = 4 can be calculated for conversion of long-term limit values into shift-related limits.

5 „Approach in an ideal world“ vs. approach in a situation where few exposure data (e.g. one single measurement) are available

To determine a excursion factor, it is necessary to know the geometric standard deviation of the distribution of measurement readings obtained for a certain activity or branch over a year. The following graph describes different ways of determining the geometric standard deviation.

Determination of GSD for calculating K_{AM}



There are various approaches to get a sufficiently precise idea of the geometric standard deviation (GSD). As long as one can recourse to a large number of valid and representative measurement data, it is often possible not only to determine the geometric standard deviation directly from the distribution, but also to indicate the 95th percentile from which the excursion factor K_{AM} can be calculated.

If measurement data are partly or completely lacking, several questions must be answered: should additional measurements be carried out and if so, is it possible - as workplaces might have changed - to conduct for instance retrospective exposure measurements, and do the potential results justify the planned financial expenditure?

If a decision in favour of additional measurements is taken, an adequate measuring concept must be available. In this case, measurements can be conducted accordingly, thus determining the geometric standard deviation. If there is no adequate measuring concept, efforts must first be geared towards the development of a measuring concept and a corresponding quality assurance system.

In the event that measurements are not wanted or impossible, there are several ways of estimating the geometric standard deviation for a specific branch or activity:

– The logbook method, i.e. the collection and use of specific product- and material parameters to estimate exposure against the background of known exposure data from comparable workplaces.

– Creating Homogeneous Exposure Groups (HEGs), i.e. exposure clustering for certain activities or branches to obtain a largely homogeneous exposure profile (little exposure variances) and thus determine a branch- or activity-specific standard deviation.

– Determining the geometric standard deviation by comparison with other workplaces, for which measurement data are available or by using generally available information (e.g. literature) to estimate the geometric standard deviation.