Editorial

Measuring compliance with exposure limits - the latest BOHS/NVvA guidance, also including potential differences between workers

It looks easy to decide whether exposure is above or below an occupational exposure limit (OEL). Surely, one can just measure a time-weighted shift exposure (if that is the sort of OEL one is using) and see whether the measurement is above or below the limit. Of course it is safer to take several measurements, but that brings problems. If you have ten measurements, and one is above the OEL, does the exposure comply or not? This kind of problem occurs very frequently in comparing exposures with a limit, because measurements are usually highly skewed, with a distribution similar to log-normal (Fig.1). Exposure depends on the interaction of many factors which vary at random and occasionally combine to produce a high value simply by chance. Unfortunately official regulations often ignore this. For example the EU Chemical Agents and Carcinogens Directives both require action if any exposure is above a limit, without allowance for exceptional high exposures occasionally happening by chance.

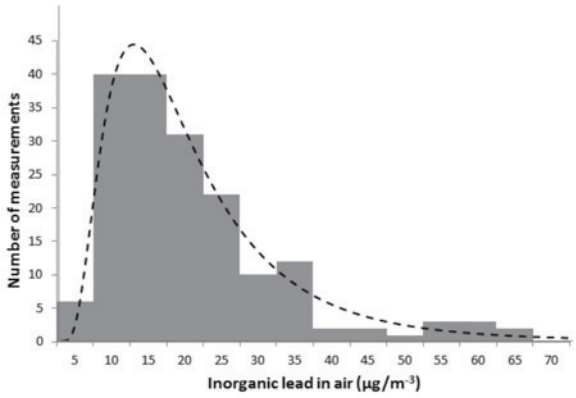

Fig 1. Measurements of lead exposure by Cope et al., taken from Rappaport and Kupper[1], with a fitted log-normal curve.

The hygienist therefore needs an agreed strategy, which says how many measurements are needed, and how far below the OEL they must be, for everyone to agree that the OEL is complied with. There have been various attempts at specifying a strategy in the past 40 years, most of which assume that exposure is log-normally distributed. Strategies use this to predict whether the great majority of exposures are below the OEL. Usually, it is regarded as satisfactory if exposure has <5% chance of exceeding the OEL (ie that the 95th percentile of the exposure distribution is <OEL). It is clearly an important requirement to do this with as few measurements as possible.

In Europe, the most influential strategy document has been the European Standard, EN689[2]. However, this does not give clear guidance on one particular strategy. Also, it fails to take account of inter-worker variability, the observation that workers who nominally have the same job are found to have very different exposure patterns for reasons that may not be obvious. All strategies begin with dividing the workforce into similarly exposed groups (SEGs), but Hans Kromhout and co-workers showed while EN689 was being discussed that there could be important differences between workers within a SEG. This is an example of how research shows strategies to be inadequate – a pattern which we can expect to continue.

In 2007 Hans Kromhout gave a paper at the British Occupational Hygiene Association conference in Newcastle on these problems. This resulted in BOHS and NVvA setting up a joint working party, with Hans and me as co-chairs. We wanted a strategy which required as few measurements as possible, gave a good degree of confidence that <5% of exposures were higher than the OEL, and took into account individual variability. A serious problem lies behind "a good degree of confidence". If the position of the 95th percentile is determined from a few measurements, then there is a lot of uncertainty on its position. This uncertainty when using a few measurements is why designing a strategy has been so difficult.

Fortunately, while the working group was discussing, a new strategy was published as part of a French regulation on compliance testing, which was based on new work by INRS at Nancy with Jérôme Lavoué of the University of Montreal. We gratefully adapted this and incorporated it into our guidance. Without going into details, the heart of this work is that what is important is not how accurately one can determine the position of the 95th percentile, but the best balance between the opposite errors of declaring a non-complying distribution "compliant", and a complying distribution "non-compliant" as a result of the statistical uncertainties. The French approach and the simulations are described more fully by Ogden and Lavoué[3] (which should be consulted for references to other material used).

The BOHS/NVvA guidance was finally issued in October 2011, and can be found on the NVvA website (http://www.arbeidshygiene.nl/~uploads/text/file/2011-12%20BOHS-NVvA%20Sampling%20Strategy%20Guidance.pdf).

[1]Rappaport SM and Kupper LL, Quantitative Exposure Assessment, ISBN 978-0-9802428-0-5, www.lulu.com (2008)
[2]European Standard EN689:1995, "Workplace atmospheres – Guidance for the assessment of exposure by inhalation to chemical agents for comparison with limit values and measurement strategy"
[3]T Ogden and J Lavoué, Testing compliance with occupational exposure limits: development of the British-Dutch guidance. J Occ Env Hyg 9:D63-D70 (2012) http://oeh.tandfonline.com/doi/pdf/10.1080/15459624.2012.663702

It involves (1) divide the workforce into SEGs; and then for each SEG, (2) make three measurements of time-weighted average exposure; if all three are <0.1*OEL compliance for the SEG can be assumed and the tests terminated; (3) make at least six more measurements of time-weighted exposure, using personal sampling; (4) use the French statistical test on the (at least) nine measurements to determine whether the group as a whole complies with the OEL; (5) apply an analysis of variance to see if the inter-worker variance is more than 20% of the total variance; (6) if it is, estimate whether more than 20% of the SEG members have >5% of their exposures greater than the OEL. If at any time any measurement is above the OEL, then the group does not comply.

The rules for distributing the nine measurements (minimum) across the SEG are fairly complicated and the guidance should be consulted. Workers to be measured should be selected at random and at least two measurements per worker and if possible three should be made, so that the between- and within-worker variances can be calculated.

This will seem complicated to the non-statistically minded, but it is possible to do the calculations and get the answer without understanding the statistics. The guidance includes details of a calculation in Excel, but recently Theo Scheffers and Tom Geens have come up with workbooks which make the calculation far simpler. These are at the moment being tested, but if all goes well I am sure they will be incorporated into the guidance and will much improve its usefulness. See Theo's website[4] for details.

We believe that the BOHS-NVvA guidance, now with Belgian, Canadian, and French input is an important step forward. From past experience, research will show its faults, but for now we hope it will be useful in this difficult problem.

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[4] *http://www.tsac.nl/websites.html*