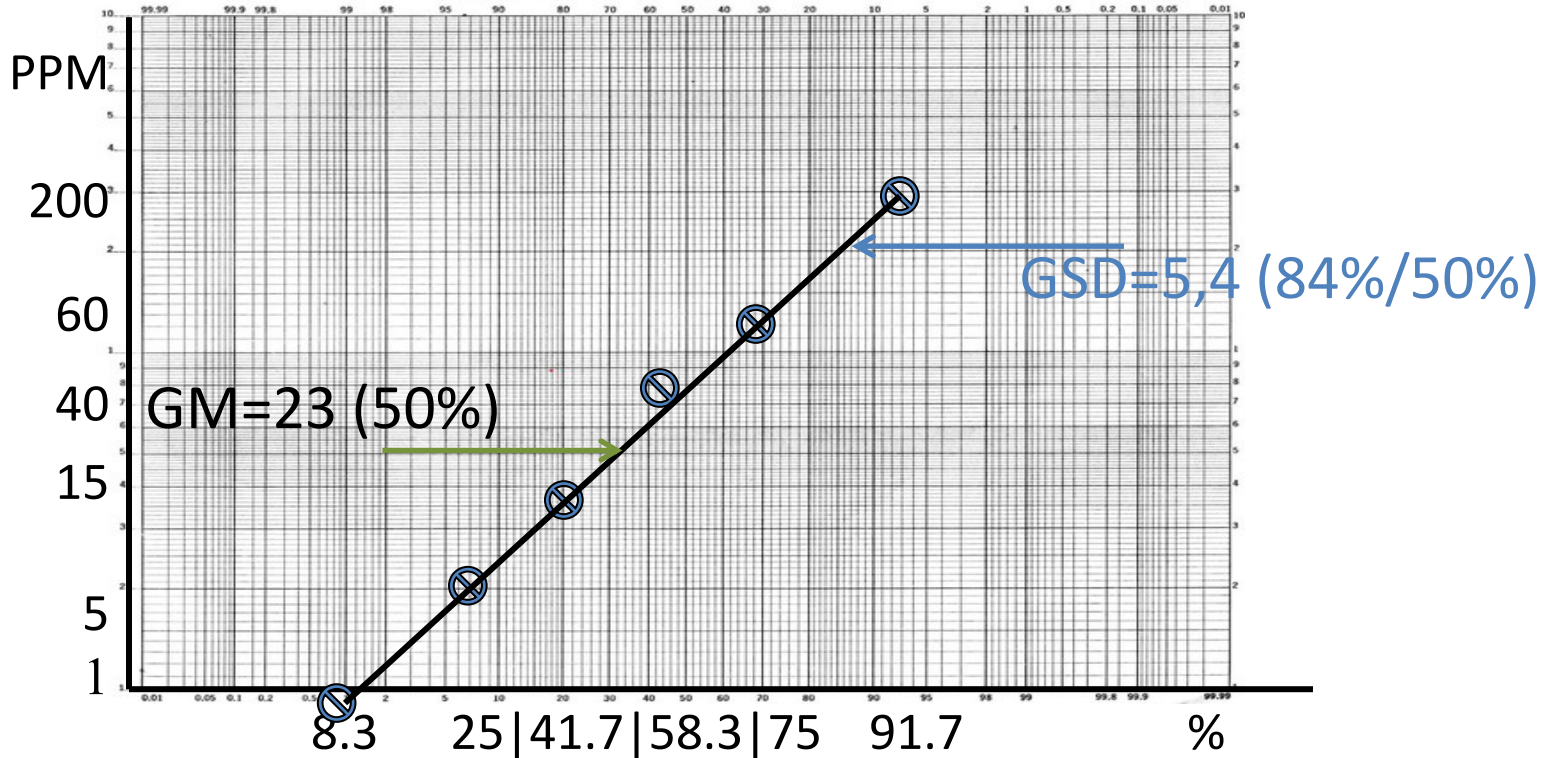


Examining exposure series

1. Lognormal goodness-of-fit
 - visual, test & transformations
2. Processing undetectables
 - (fraction LoD), regression, degrees of freedom
3. GSD values (5.4.2)
 - Too low, too high, all is possible
4. Individual outliers
 - Location, dispersion, between and within

LogNormal probability paper and NOS regression

Outcome, logarithmic scale

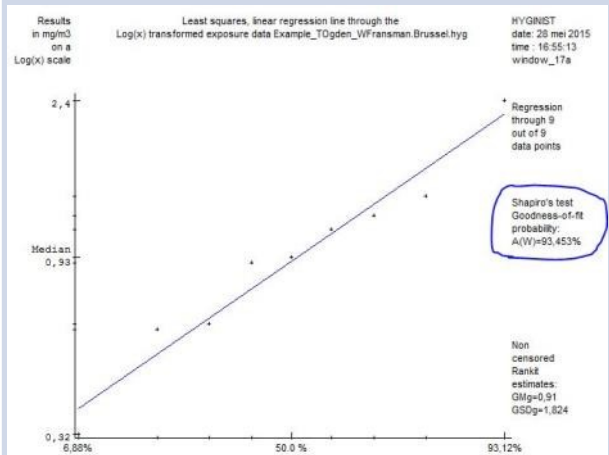


Rankit or Normal Order Statistics

Annex E .1.1 through 1.4

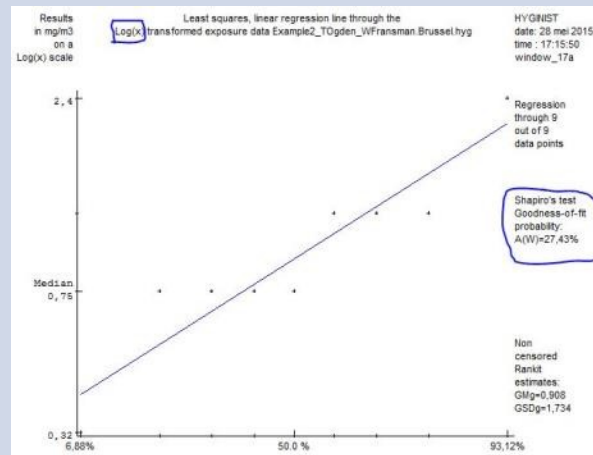
Lognormal plot and Shapiro test

Continuous outcome



P_{SW}

Discrete data



P_{SW}

Single outlier

P_{SW}

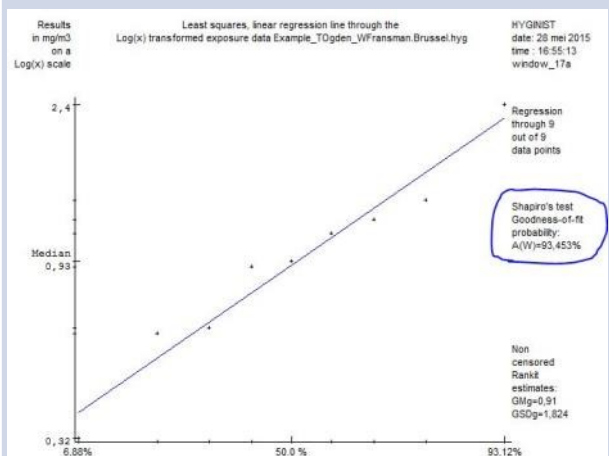
Detection limit

P_{SW}

Annex E.1 and E.2 In series up to 9 samples, omnibus goodness-of-fit tests (including Shapiro) will hardly reject Lognormality based on a 5% criterion

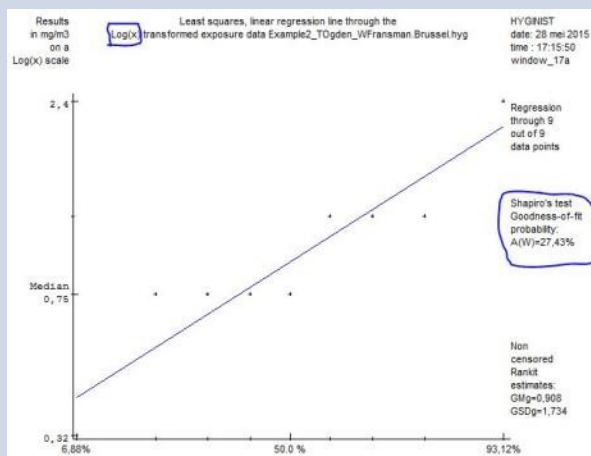
Goodness-of-fit plot and test (Annex E.1 and E.2)

Continuous outcome



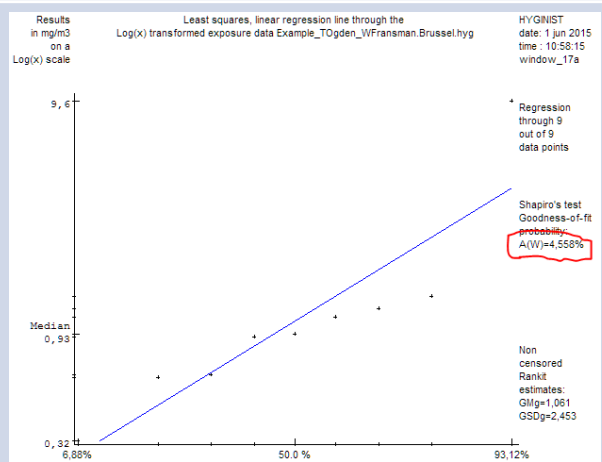
$P_{SW}=93\%$

Discrete outcome



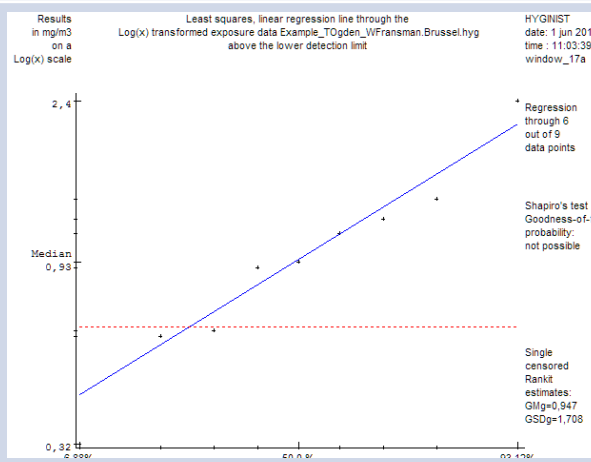
$P_{SW}=27\%$

Single outlier (9,6 in stead of 2,4)



$P_{SW}=4.5\%$

Detection limit

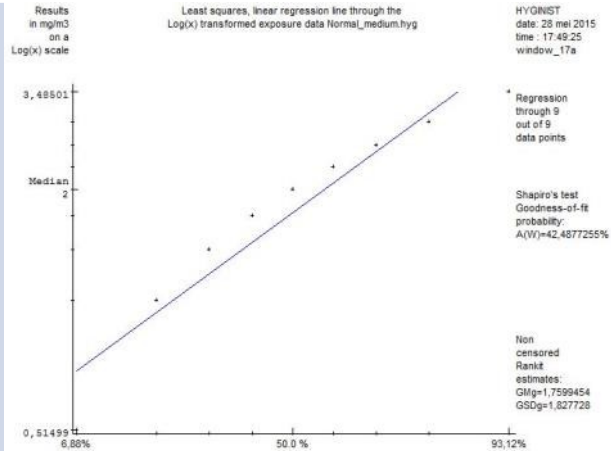


$P_{SW}=n.a.$

In series up to 9 samples, plot and omnibus tests (Shapiro by preference) help to validate SEG and Lognormality

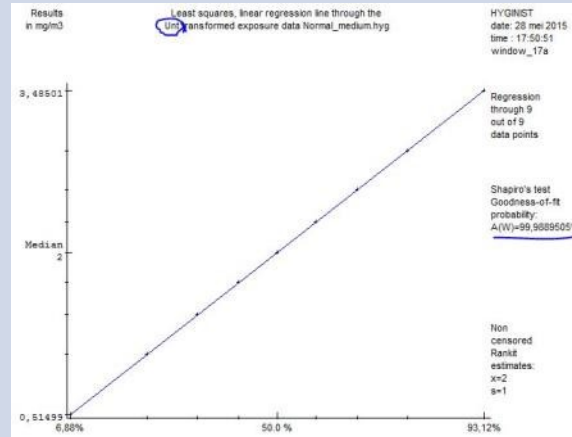
Compare transformations

log



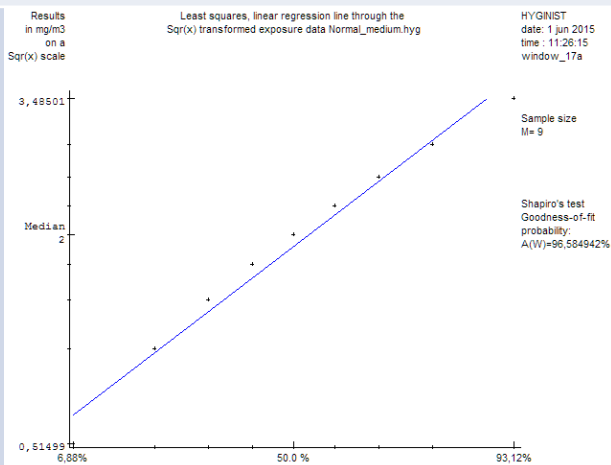
$P_{SW}=43\%$

untransformed



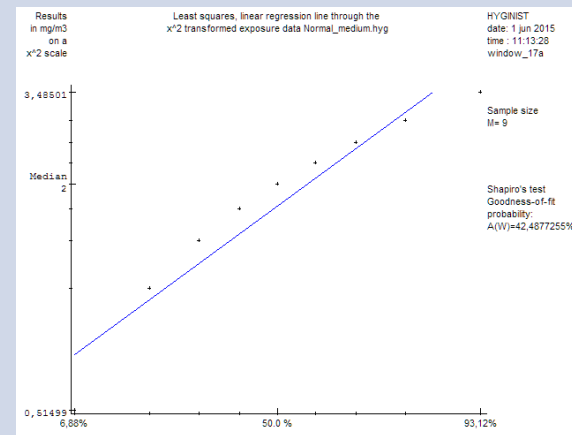
$P_{SW}>99.9\%$

Square root



$P_{SW}=97\%$

Squared



$P_{SW}=42\%$

Annex E.1 and E.2 Graphical and statistical tests help to assess if the exposure distribution can be represented by the lognormal model.

Recommendations 5.4 & Annex E.3.3

- Lognormality is the null hypothesis (H_0)
- to accept or reject H_0 use for sample size ($N=3 \rightarrow 9$):
 - Probability paper, and
 - An omnibus test (preference Shapiro), but no criterion, and
 - Compare different transformations (un-, log-, etc.)
- For higher sample size and nondetects consult expert

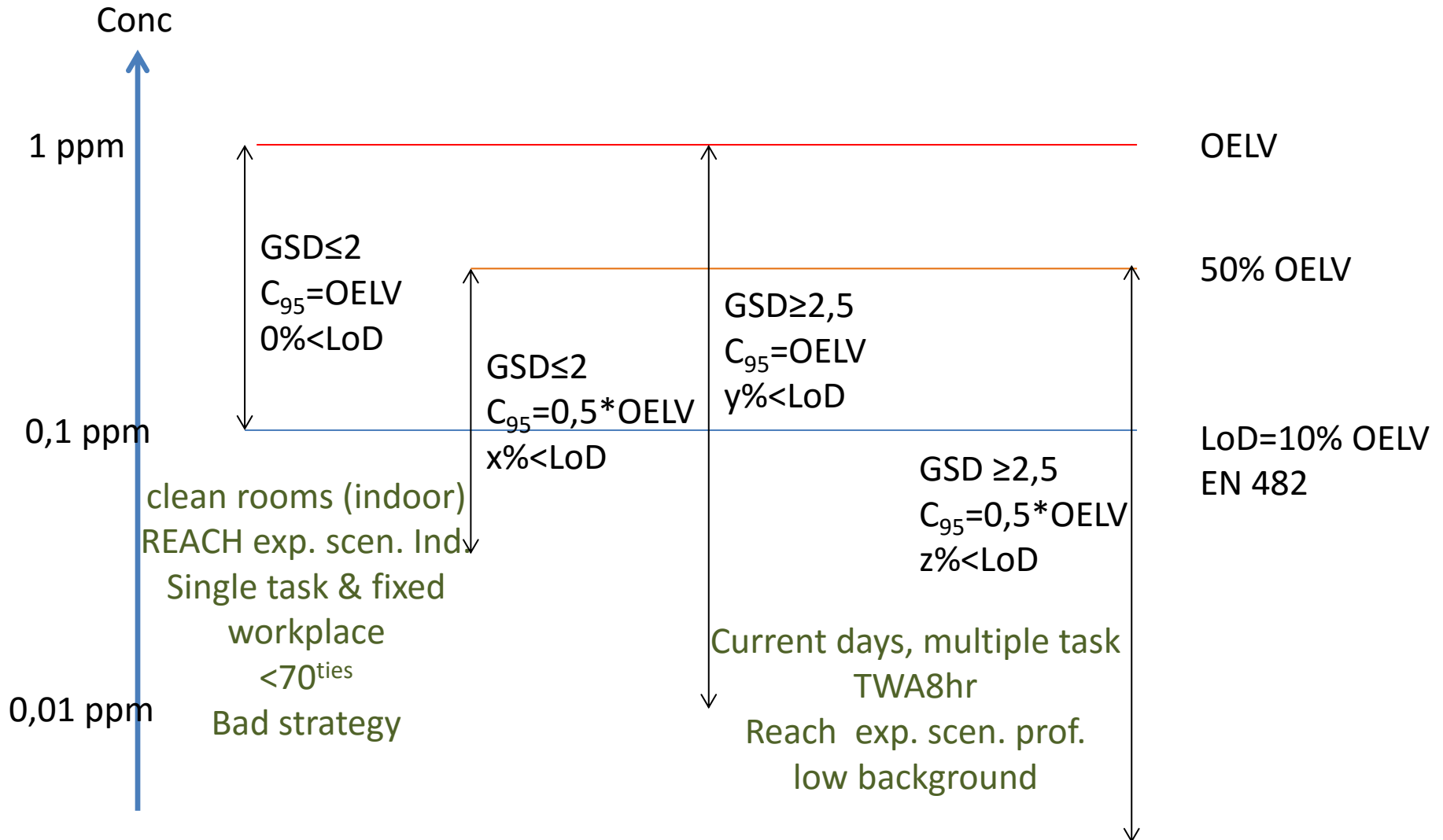
Examining exposure series

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The urgency to treat undetectables more professionally (~~0,5*LoD~~)

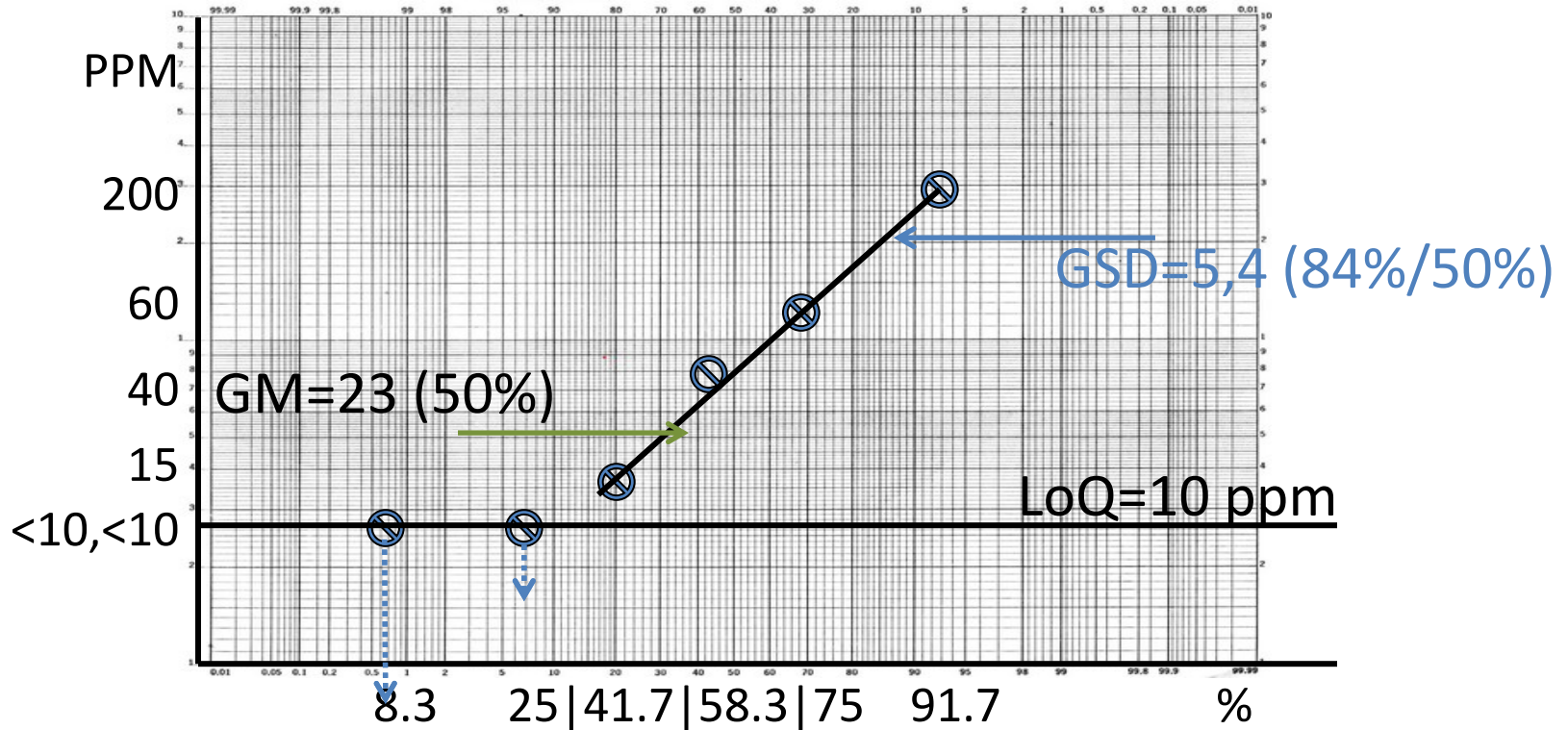
- Overestimation of GM
- Underestimation of GSD and $C_{95\%}$
- Changing working patterns
- Trends in time
- IH reputation

The urgency to treat undetectables more professionally (~~0,5*LoD~~)



NOS regression through the detectables

Outcome, logarithmic scale



Rankit or Normal Order Statistics

Degrees of freedom

- If the extrapolation space increases, the number of degrees of freedom df decreases
- Small sample size (& small # detectables) increases exceedance probability

Degrees of freedom (df)

Small sample size (N) and undetectables (N-k):

- decrease df
- increase the extrapolation space
- increase noncompliance probability, in noncStudent, unbiased, nonPar methods

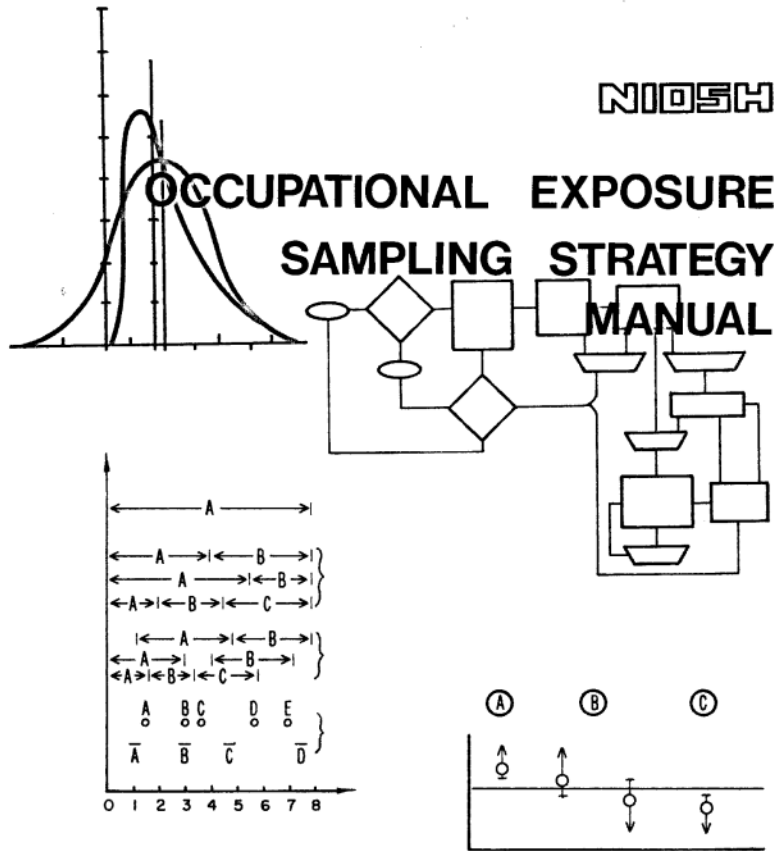
The influence of $k < N$ detectables on df: $N=9, K=3$

- $df=k-1$ (Krishnamoorthy) , $df=5$
- $df=N-1$ (NDExpo, BWStat) $df=8$
- $df=\text{Int}((N+k)/2)-1$ (HYGINIST) $df=7$

Non-detects in Industrial Hygiene

- Annals Occupational Hygiene (2009-2010, *Large sample solutions*):
 - [Ogden](#). Editorial: Handling results below the level of detection.
 - [Helsel](#). Incorporating Non-detects in Science.
 - Flynn. Analysis of censored exposure data by the Shapiro-Wilk W statistic.
- BOHS-NVvA guidance: “It is not recommended simply to substitute $LoQ/2$ or $LoQ/\sqrt{2}$ for each value $<LoQ$ ”
- Software (probability paper, regression):
 - HYGINIST (1990, small samples solution), Altrex, IHDataAnalyst, NDExpo, BW_Stat (2014)

NIOSH 1977: be ware of constant background exposure



U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Center for Disease Control
National Institute for Occupational Safety and Health

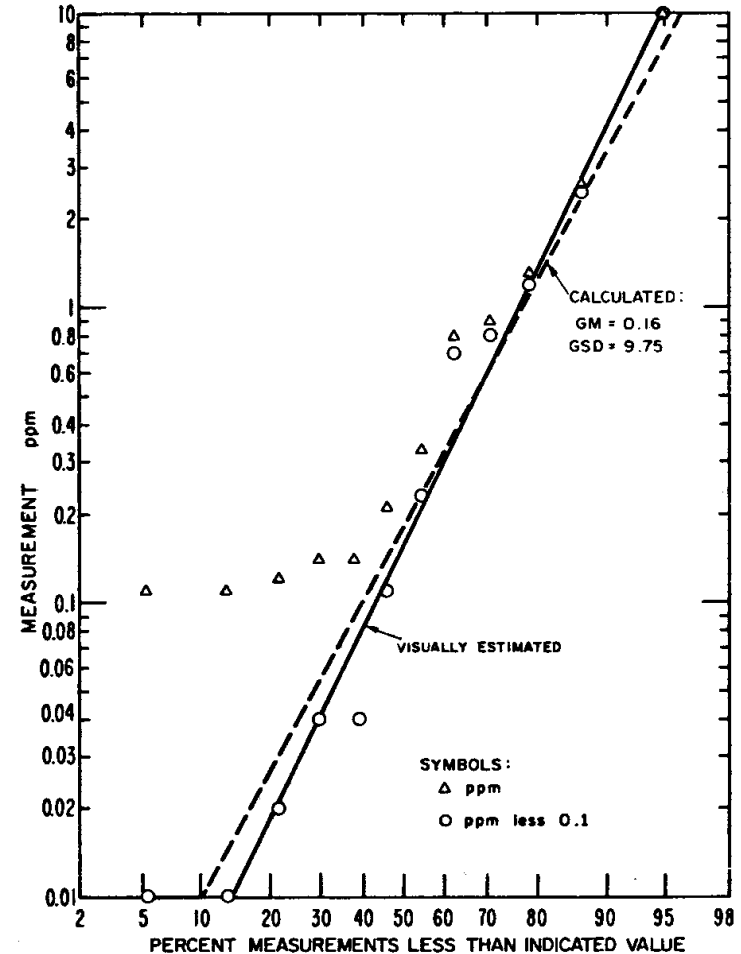


Figure I-4. Hydrogen fluoride measurement distribution.

Theory censored samples

- **Helmut Schneider. Truncated and censored samples from Normal populations. Statistics: textbooks and monographs. Vol 70 (1986).**
- Galton, F. Speeds of trotting horses. Proc. Royal Soc. 62 (**1898**) 310-314.
- Fisher R.A. The truncated Normal Distribution. British Assoc. Adv. Sci. Math. Tables I, **1931** pp XXXIII
- Lotz A. Statistische Analysemethoden für linkszensierte Variablen. IPA, Bochum (2013)
- “LoQ/x” methods never recommended



**Estimating GM and GSD from sampling
data with undetectables**

**Regression through the data above LoD
and optimizing GM and GSD using
Shapiro & Wilks Goodness-of-Fit**

HYGINIST 4.2.3

NVvA BOSH guidance

3.7 Treatment of values < LoQ

- “There are ML, regression & Shapiro & Wilks methods.”
- Included in BW_Stat for group and individuals

BW_Stat Startup screen

Testing Compliance with Occupational Exposure Limits for Airborne Substances, Sept. 2011

Manual

Tab Start and Manual

Tab Data

Tab Report

Tab Examples

Disclaimer

1. Select your language:	English
2. Enter the name of the substance:	Cotton dust
3. Enter the units of measurement:	mg/m ³
4. Enter the occupational exposure limit (OEL):	1.70 mg/m ³
5. Enter the lower limit of quantification (LoQ=accuracy): Also to be read out from the lognormal probability plot	0.17 mg/m ³
6. Optional input of the analytical lower detection limit (L ₀):	0.04 mg/m ³

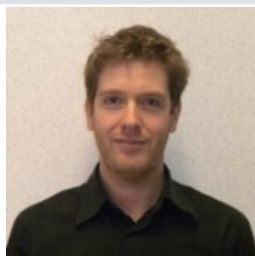
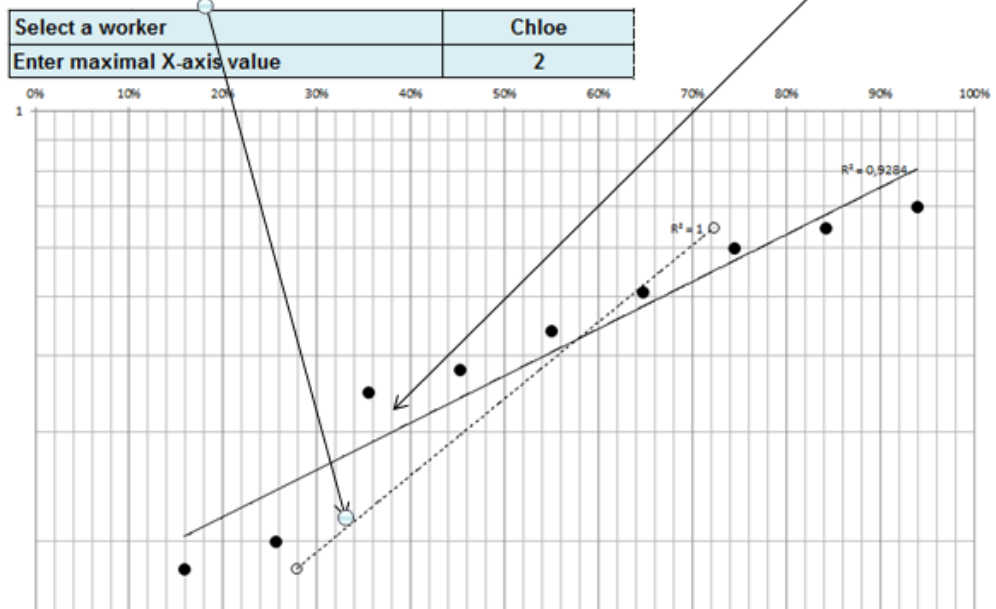
7. Enter in the tab "Data" the measured concentration levels, taking following into account:
Make sure the unit in which the data are expressed is the same as the unit of OEL, LoQ and LoD.
Enter in column 2 all sampling dates (obliged input), top down, avoiding any blank cells (yellow field), maximum 50 dates allowed.
Enter in row 2 all worker IDs (obliged input) from left to right avoiding any blank cells (yellow fields), maximum 50 workers allowed.
Enter the measurements for all date/worker combinations (light blue fields); if a certain combination has no outcome, then leave this cell blank.
Enter the measurements <LoQ without adjustments as numeric values.
Background colour shifts from green (<10% OEL) via orange (=50%OEL) to red (>100%) if the measurement result shifts towards the OEL.

8. Tab Report pictures the compliance testing in four steps (stages) according to the BOHS/NVvA guidance and flowchart below.

9. Use BW_Stat only after reading the Disclaimer right to the flowchart.

Fig 5. Flowchart of the process (from the guidance, page 19)

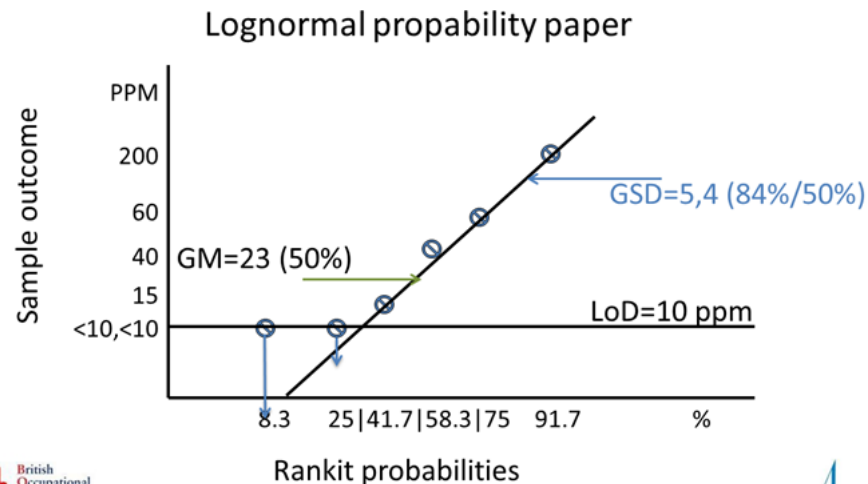
Lognormal probability plot for group and selected worker



Recommendation

- a simple annex on graphical treatment of non-detects
- adjacent to/combined with Annex E proposal
- No promotion of “short cut” methods (i.e. LoQ/2)
- Refer to IH free-ware, doing the job in a reproducible way

Handle non-detects graphically



Proposed text

Valid measurement methods used to measure workplace air exposure must comply with CEN 482 prescribing its range includes at least 0.1 through 2 times the OELV with a x% accuracy.

This however does not prevent the occurrence of outcome outside that range. In Annex “X” some methods are given for an unbiased estimate of the exposure distribution in the presence of outcome outside the detection range

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