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Van BWStat naar BWStat Web?

26th NVvA Symposium

Beriepziekten; beroepsziekten verleden tijd?!

Session T: NEN-EN 689 naar 2.0, hogere (werkplek)atmosferen

Contact

BSOH & Provikmo

dr. ir. Tom Geens
voorzitter/président BSOH
tom.geens@bsoh.be
twitter.com/tgeens
linkedin.com/in/tomgeens

BELGIAN SOCIETY FOR OCCUPATIONAL HYGIENE

BSOH vzw/asbl
Maatschappelijke zetel/Siège social
Kapucijnenvoer 35/5 B-3000 Leuven

info@bsoh.be
www.bsoh.be

dr. ir. Tom Geens
Wetenschappelijk medewerker

Provikmo ADMB preventie

t +32 (50) 474 805
tom.geens@provikmo.be

Provikmo vzw – Studie- en documentatiedienst
Dirk Martensstraat 26 – B-8200 Sint-Andries (Brugge)

http://www.slideshare.net/tgeens/standing-up-for-occupational-hygiene

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- verspreiding en uitwisseling kennis
- naambekendheid vergroten
- nationale en internationale samenwerkingen

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What's covered in these slides?

Numbers, numbers, numbers,…

- The new EN 689 focusses on compliance testing
- The procedure of collecting measurement results, checking their quality, pooling them between workers in the SEG during the same campaign (or different campaigns) is more formally described than in the old EN 689, some annexes are challenging
- You will need to do some more math…
- How will you manage to do this?

Draft prEN 689

Workplace exposure — Measurement of exposure by inhalation to chemical agents — Strategy for testing compliance with occupational exposure limit values

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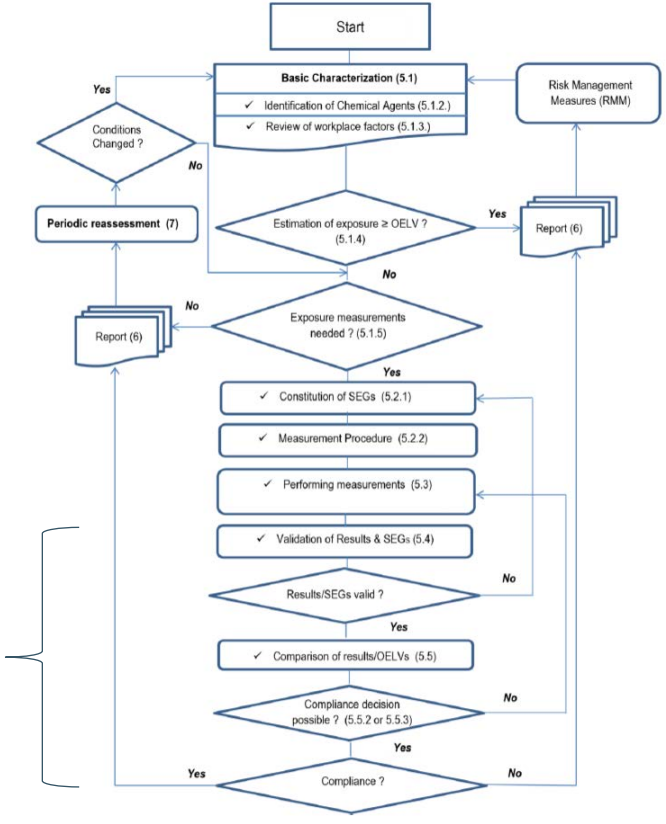
What's covered in these slides?

A summary of validation and testing procedures



Validity of each individual result and the SEG as a whole

Two necessary quality checks to be performed!

- The validity check has to be performed for each sample separately as well as for the SEG as a whole

5.4 Validation of results and SEGs

5.4.1 General

Before testing compliance with the OELV it is necessary to consider the validity of each measurement and to use the measurements to evaluate the constitution of the SEG for testing compliance as explained in clause 5.5.

- For further guidance, the text refers to annex E for both parts
- You “shall” analyse log probability plots (boxplots not mentioned)

Exposure measurements are usually log normally distributed. To check whether all individuals belong to the same SEG, and whether the distribution of measurements is log-normal, the log probability plot of the data shall be analysed. Guidance is given in Annex E.

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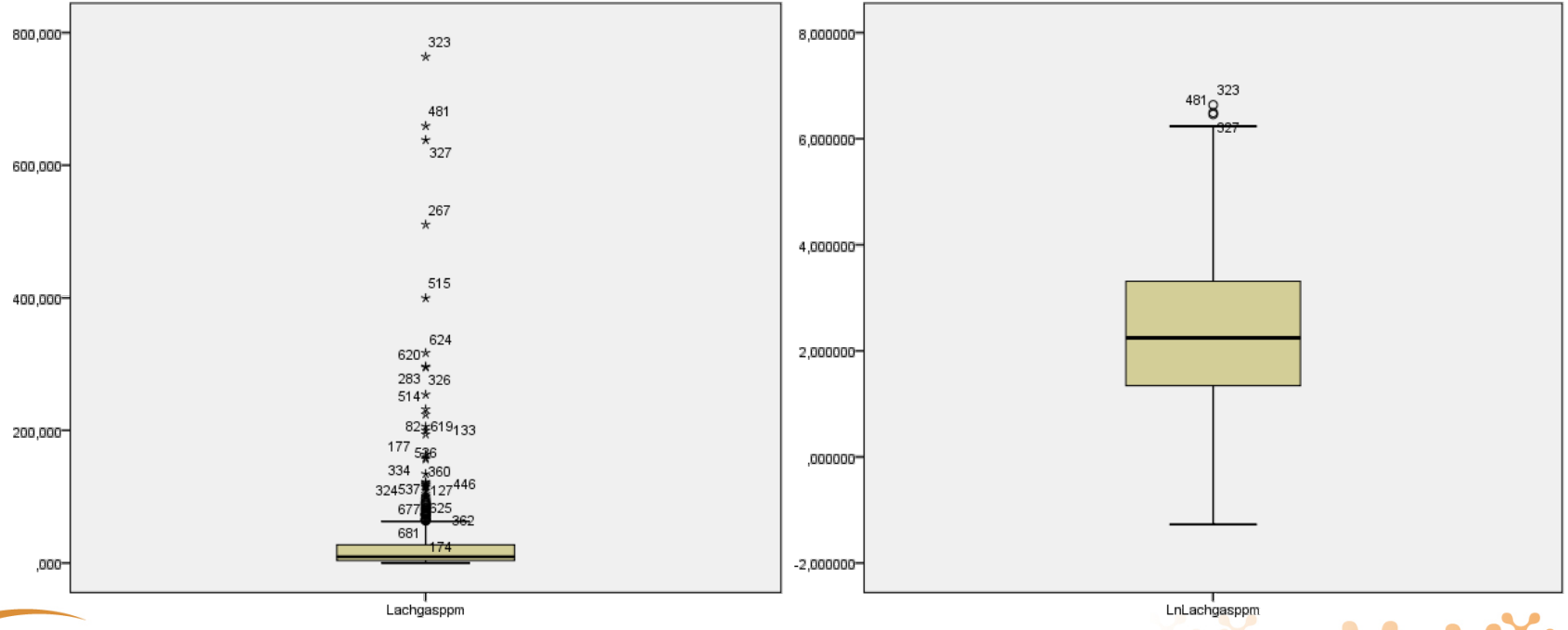
Validity of each individual result

An N_2O example to illustrate the context dependancy

- an identified outlier (o) or extreme (*) in a normal model is not the same as in a lognormal model (more on boxplots here and here)



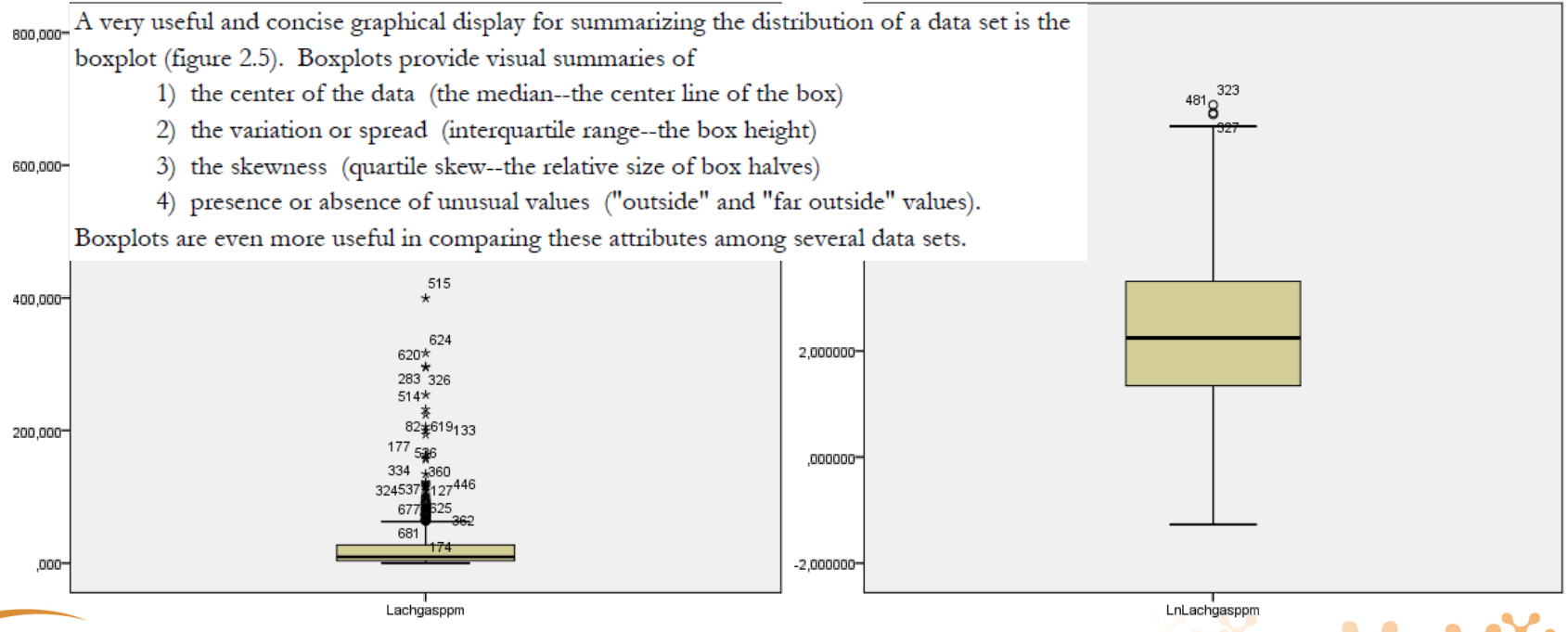
Validity of the SEG as a whole: visual check with boxplots

Measurement results need to follow the same distribution as assumed in the (statistical) compliance test (5.4.3) + appraisers assume lognormality (5.5.3)

A very useful and concise graphical display for summarizing the distribution of a data set is the boxplot (figure 2.5). Boxplots provide visual summaries of

1) the center of the data (the median--the center line of the box)
2) the variation or spread (interquartile range--the box height)
3) the skewness (quartile skew--the relative size of box halves)
4) presence or absence of unusual values ("outside" and "far outside" values).

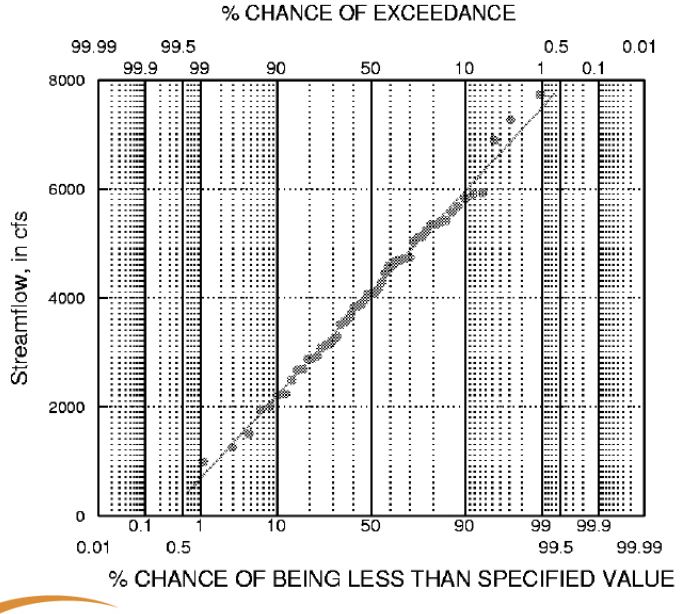
Boxplots are even more useful in comparing these attributes among several data sets.

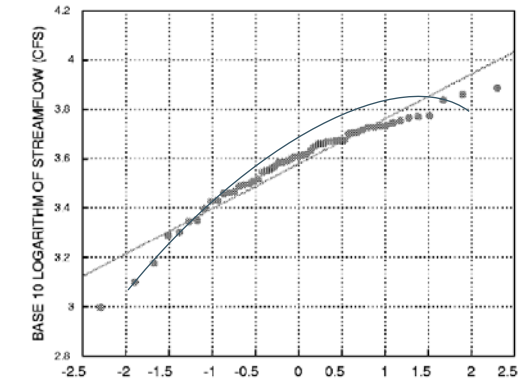


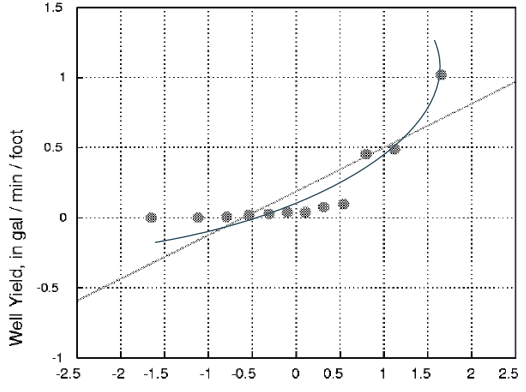
Validity of the SEG as a whole: visual check with qqplots

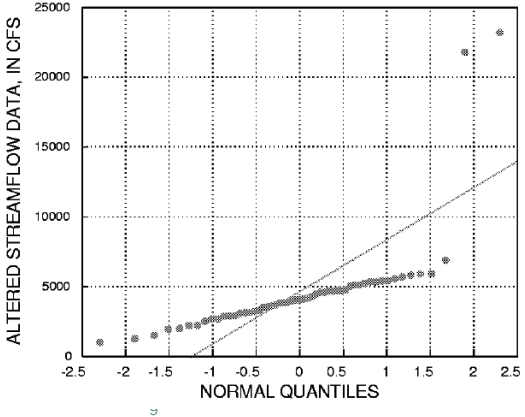
Examples from Statistical Methods in Water Resources (Helsel and Hirsch)

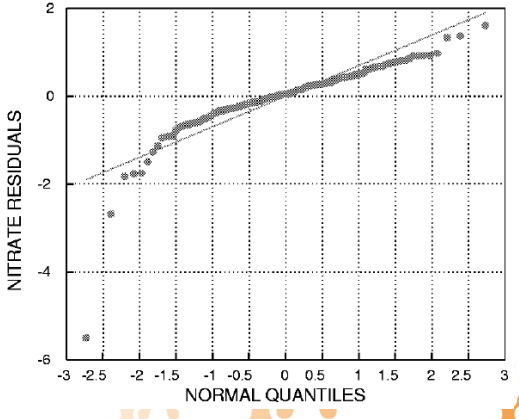
- flying banana's and S-curves are indications for deviation of normality
- patterns deviating from a lines indicate problems











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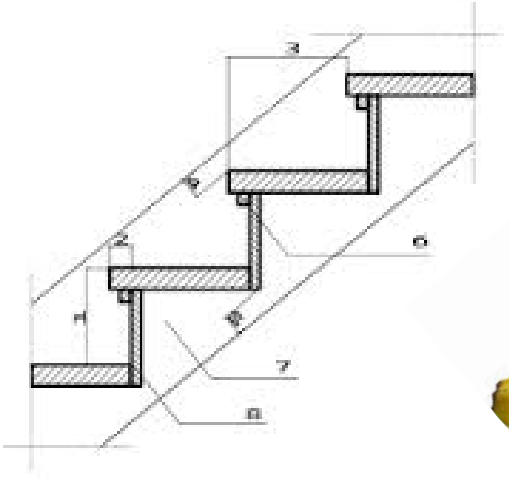
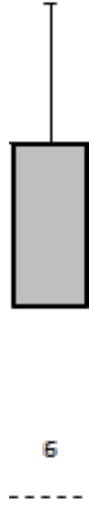
Validity of the SEG as a whole: visual check

a picture is worth a thousand words...

- Boxplots: extremes (*), outliers (o), assymmetry, large difference between upper and lower part of the IQR (box), squeezed parts?
- QQ-plots: staircases, banana's, S-curves or other apparent deviations from straight lines?





How can you do qqplots in excel?

Or on real log probabilty paper if you'd like…

- Enter the concentrations "x_k" and calculate the plotting positions "P_k" ("k"-3/8)/("tot number of concentrations = k_{max}"+1/4)

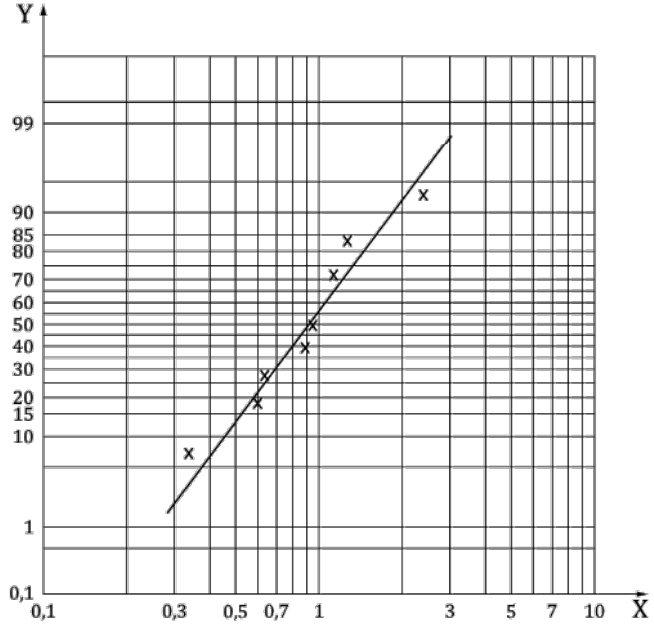
Table E.1 — Example of nine exposure measurements with the associated probability values for plotting on log-probability paper.

Exposure x_k mg m^{-3}	k	P_k	P_k as percentage
0,32	1	0,068	6,8
0,60	2	0,176	17,6
0,62	3	0,284	28,4
0,90	4	0,392	39,2
0,93	5	0,500	50,0
1,1	6	0,608	60,8
1,2	7	0,716	71,6
1,35	8	0,824	82,4
2,4	9	0,932	93,2

How can you do qqplots in excel?

Or on real log probabilty paper if you'd like…

- calculate the "z-scores" (a linear scale) for the %s (=NORM.S.INV("P_k"))
- insert a scatterplot with h-axis = exposure (log-scale) and v-axis = z-score



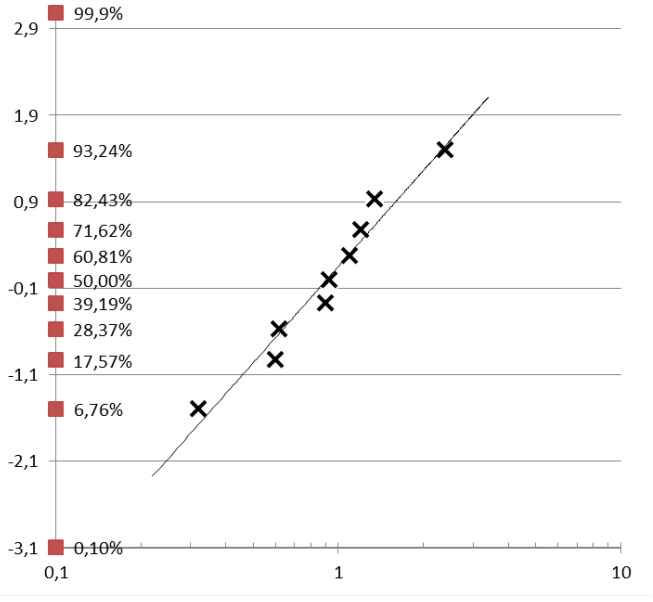


Figure E.1 — Nine exposure measurements and their probability values plotted on log-probability paper.

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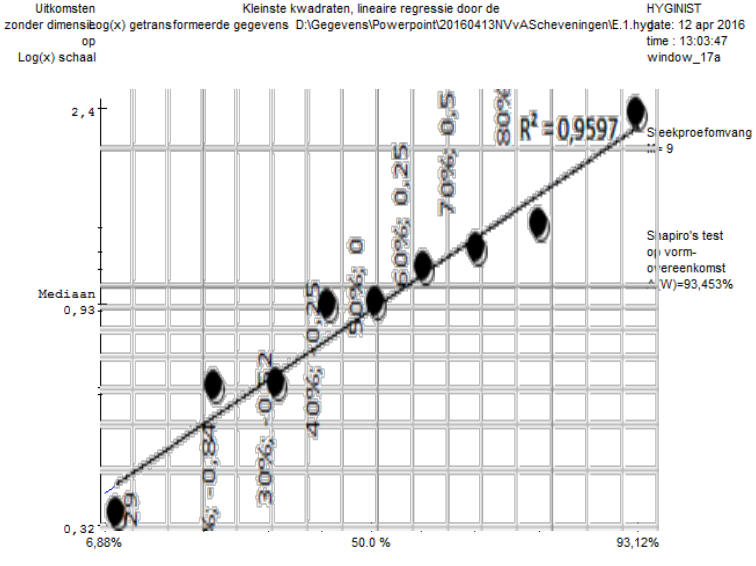
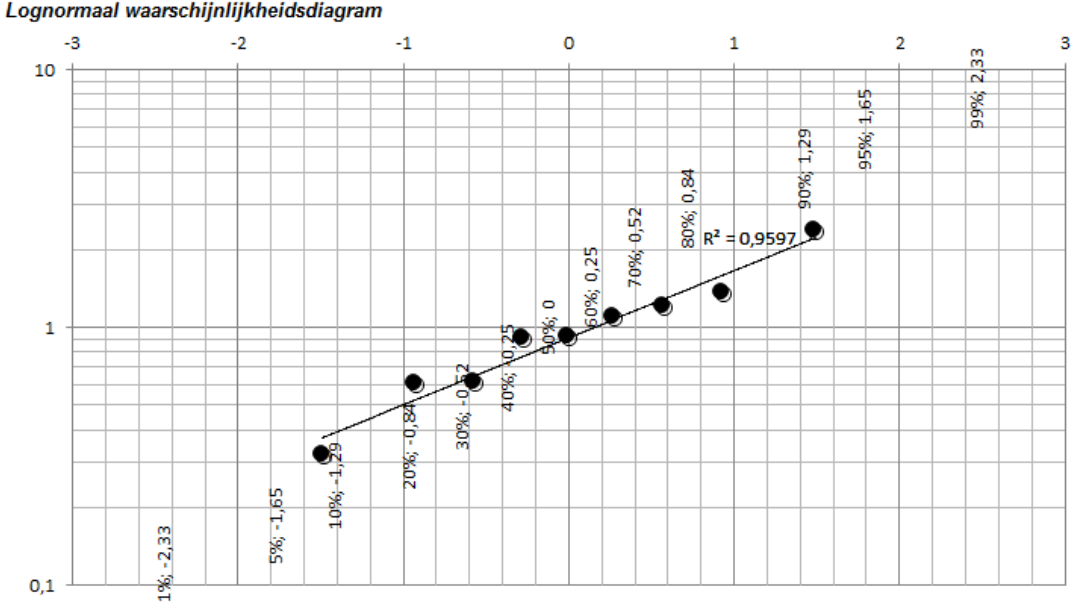
Much easier: use Hyginist or BWStat

Or on real log probabilty paper if you'd like…

- Hyginist E.1
- BWStat E.1





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Much easier: use Hyginist or BWStat

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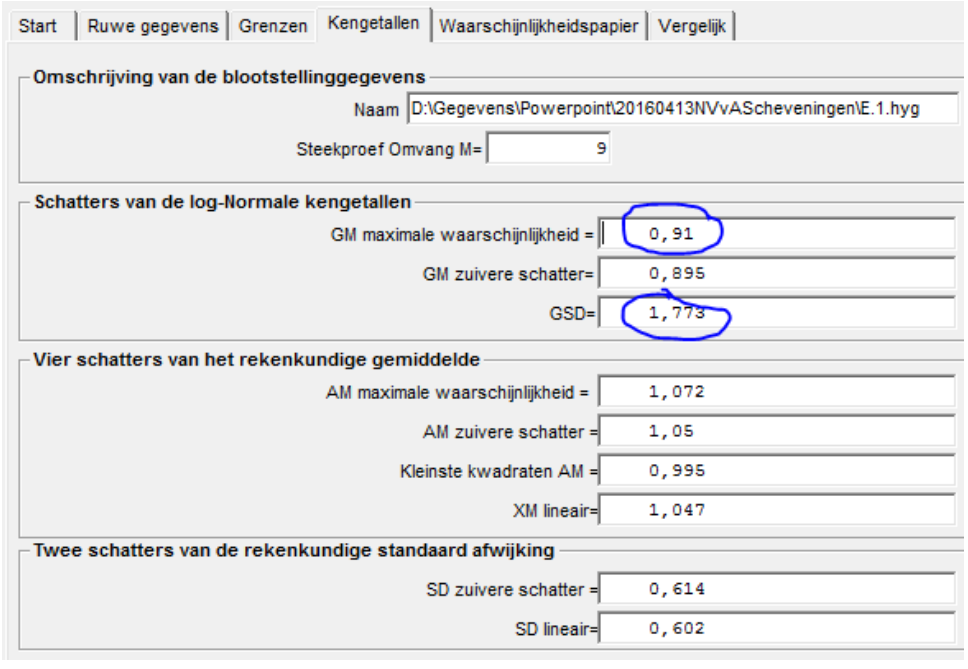


Individuele statistieken

	AM	AStdev	GM	GStdev	Shapiro-Wilk	Shapiro-WilkCrit	U	UCrit95%,70%	UTL95%,70%	GMGraph (intercept)	GStdevGraph (slope)	UGraph	UCritGraph95%,70%	UTLGraph95%,70%	aantal > OEL	Lognormal	Compliant95%,70%	df (aantal -1)	CompliantGraph95%,70%	df (aantal > LoQ -1)
	Calculated parameters									Regression estimators					Summary					
Groep	1,05	0,60	0,91	1,77	0,98	0,83	2,98	2,04	2,92	0,91	1,82	2,84	2,04	3,08	0	1	1	8	1	8

Much easier: use Hyginist or BWStat

Also to illustrate the relative importance of eyeballing vs statistical testing

- Hyginist E.1
- BWStat E.1

E.3 Statistical methods for the validation of SEGs

More rigorous statistical tests of the fit of the lognormal and other distributions to exposure results are included in data-handling software (for example Altrex Chimie, BWStat, IHDataAnalyst, IHStat, etc) but the power of such tests to identify non-lognormality is limited for the small sample numbers considered here. For example, of the cases presented in E.2, only the data in Figure E.5 is identified by the Shapiro and Wilk test [3] as inconsistent with a lognormal distribution. .

Testing Compliance with Occupational Exposure Limits for Airborne Substances, Sept. 2011
BWStat v2.1

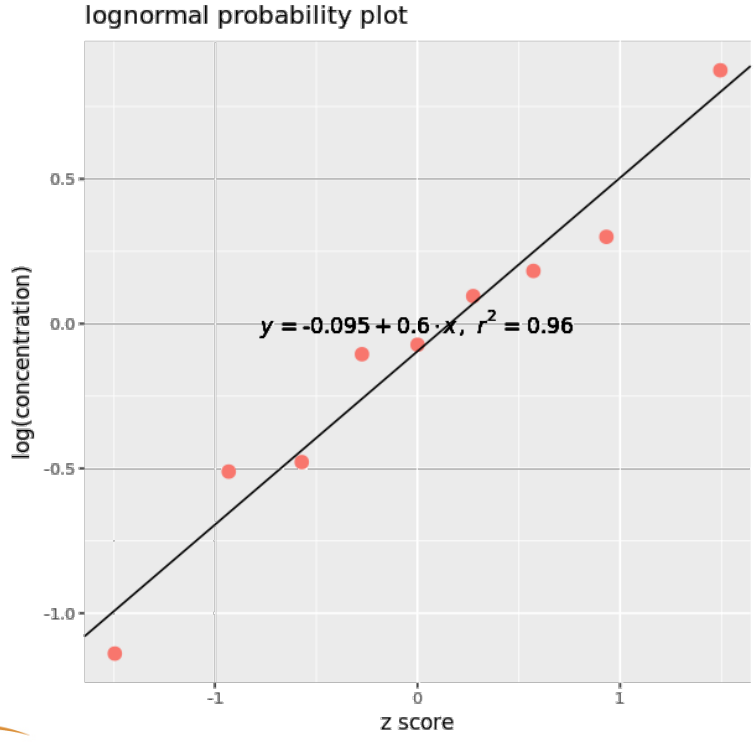
Individual statistics

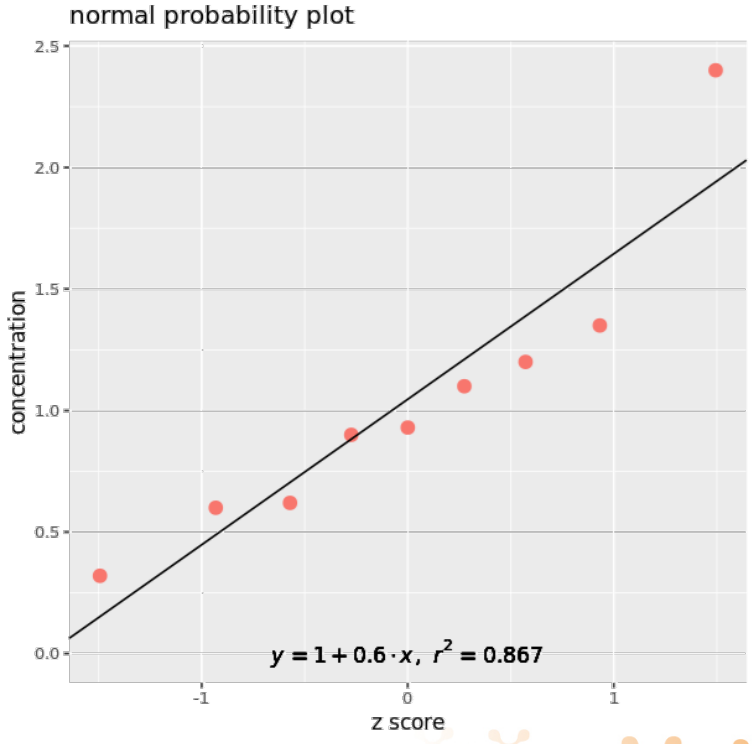
	AM	AStdev	GM	GStdev	Shapiro-Wilk	Shapiro-WilkCrit	U	UCrit95%,70%	UTL95%,70%	GMGraph (intercept)	GStdevGraph (slope)	UGraph	UCritGraph95%,70%	UTLGraph95%,70%	number > OEL	Lognormal	Compliant95%,70%	df (number -1)	CompliantGraph95%,70%	df (number > LoQ -1)
	Calculated parameters									Regression estimators					Summary					
Group	1,26	1,25	0,92	2,16	0,97	0,95	2,19	1,77	3,61	0,92	2,16	2,19	1,77	3,62	1	1	1	54	1	54
E.3a (lowest GM)	0,54	0,27	0,48	1,80	0,94	0,76	4,00	2,29	1,83	0,48	1,86	3,76	2,29	1,99	0	1	1	4	1	4
E.3b (highest GM)	1,34	0,42	1,30	1,35	0,97	0,76	4,50	2,29	2,57	1,30	1,39	4,14	2,29	2,73	0	1	1	4	1	4
Individuals																				
E.1	1,05	0,60	0,91	1,77	0,98	0,83	2,98	2,04	2,92	0,91	1,82	2,84	2,04	3,08	0	1	1	8	1	8
E.2	0,94	0,57	0,77	2,06	0,96	0,83	2,58	2,04	3,37	0,77	2,13	2,47	2,04	3,60	0	1	1	8	1	8
E.3a	0,54	0,27	0,48	1,80	0,94	0,76	4,00	2,29	1,83	0,48	1,86	3,76	2,29	1,99	0	1	1	4	1	4
E.3b	1,34	0,42	1,30	1,35	0,97	0,76	4,50	2,29	2,57	1,30	1,39	4,14	2,29	2,73	0	1	1	4	1	4
E.4	1,37	1,15	1,06	2,08	0,94	0,83	2,12	2,04	4,70	1,06	2,13	2,05	2,04	4,95	0	1	1	8	1	8
E.5	0,95	0,40	0,84	1,81	0,82	0,83	3,00	2,04	2,81	0,84	1,78	3,11	2,04	2,70	0	0	1	8	1	8
E.6	2,32	2,51	1,28	3,43	0,97	0,83	1,10	2,04	15,76	1,28	3,69	1,04	2,04	18,27	1	1	0	8	0	8

...or BWStat Web?

e.g. for comparing lognormal and normal probability plots

- BWStat Web E.1





Validity of of the SEG as a whole: the BW complication

An important complication is the phenomenon between-worker variability

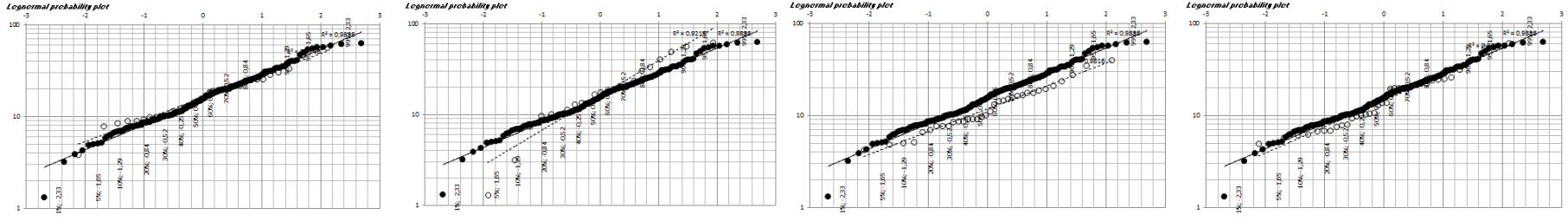
- This issue is dealt with in detail in the BOHS-NVvA sampling strategy…

An important complication is that two workers doing the same job may not have the same exposure. This phenomenon, known as between-worker variability, means that measurements of one worker's exposure cannot simply be assumed to apply to others doing nominally the same job. Furthermore, exposure varies from shift to shift, giving rise to within-worker variability.

If the measurements show that one or more workers have exceptional exposure, which seems inconsistent with the distribution of results from the rest of the SEG, the reasons shall be investigated and these workers may be treated separately, for example forming a new SEG and taking more measurements as necessary. Guidance is given in Annex E. It may be necessary to repeat exposure measurements to have sufficient representative measurements for each SEG to test compliance.

Any changes to the SEG as a result of these tests shall be recorded in the report (see Clause 6).

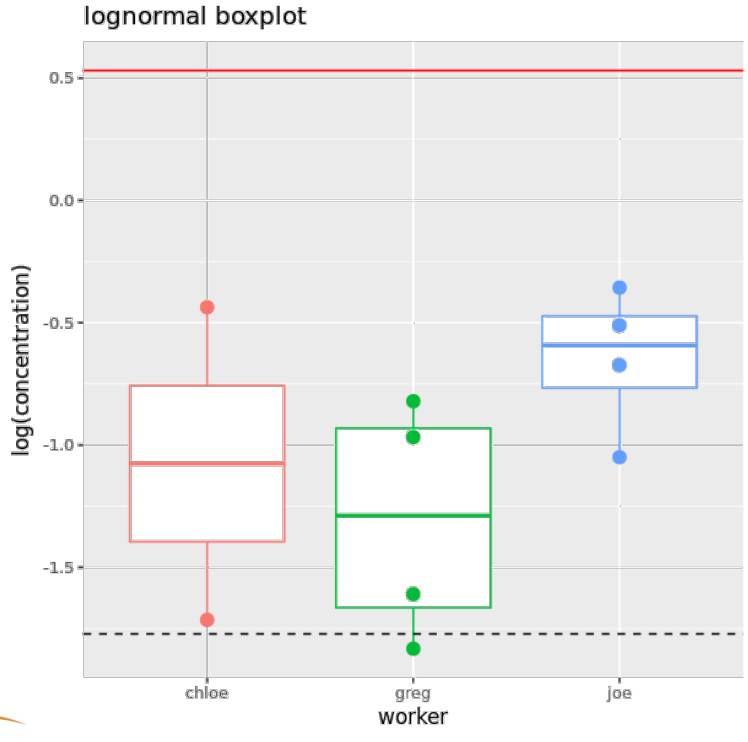
- … and BWStat remains usefull for the visual checks required in prEN689 (in which graph the line through the open circles has the worst fit???)

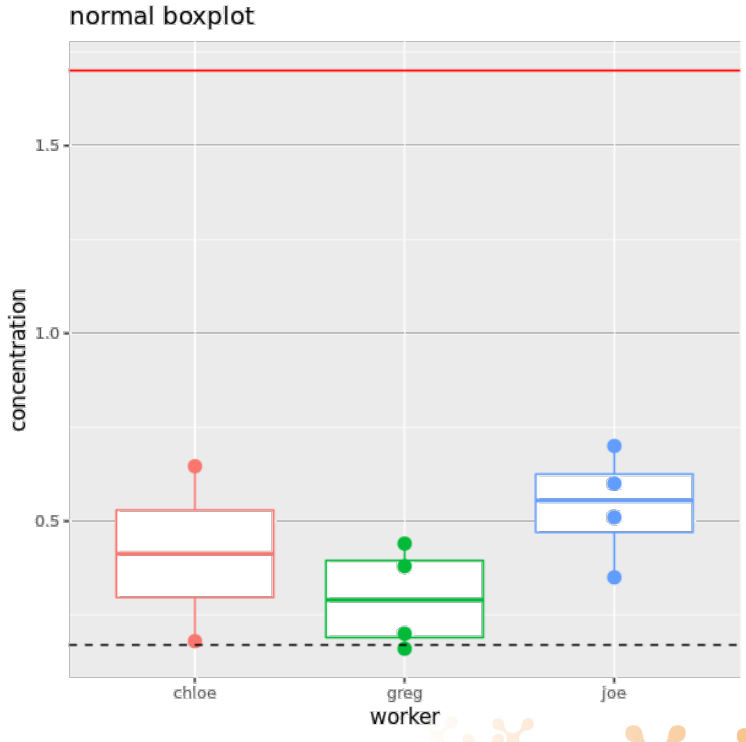


...or BWStat Web

e.g. for comparing lognormal and normal boxplots per worker

- BWStat Web Cottondust





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The preliminary test …

Requires 3 – 5 measurements on workers belonging to a SEG

5.5.2 Preliminary test

The preliminary test requires three to five valid exposure measurements (see 5.4) on workers belonging to a SEG.

a) If all results are below:

   1) 0,1 OELV for a set of three exposure measurements or,

   2) 0,15 OELV for a set of four exposure measurements or,

   3) 0,2 OELV for a set of five exposure measurements.

   Then it is considered that the OELV is respected: **Compliance**.

b) If one of the results is greater than the OELV, it is considered that the OELV is not respected: **Non-compliance**.

c) If all the results are below the OELV and one result is above 0,1 OELV (set of three results) or 0,15 OELV (set of four results) or 0,2 OELV (set of five results) it is not possible to conclude on compliance with the OELV. **No-decision.** In this situation additional exposure measurements shall be carried out (requiring at least at total of six measurements) in order to apply the test based on the calculation of the confidence interval of the probability of exceeding the OELV, as specified in 5.5.3.

… seems to be on the safe side

Requires 3 – 5 measurements on workers belonging to a SEG

- OEL Thresholds proposed in the screening test are based on table VII in ND2231, the calculation method is detailed in the annex of the ND 2231.
- http://www.inrs.fr/media.html?refINRS=ND%202231

TABLEAU VII

Fraction de VL, en fonction de l'écart-type géométrique et du nombre de mesures, que le maximum d'une série ne doit pas dépasser, correspondant à une probabilité de dépassement inférieure ou égale à 0,01.

LV fraction, with respect to geometric standard deviation and number of measurements, which the series maximum must not exceed, corresponding to a probability of exceeding less than or equal to 0.01.

Nombre de mesures	Écart-type géométrique					
	1,1	1,5	2	2,5	3	4
1	0,80	0,39	0,20	0,12	0,08	0,04
2	0,84	0,48	0,28	0,19	0,14	0,08
3	0,86	0,53	0,34	0,24	0,18	0,11
4	0,88	0,57	0,38	0,28	0,22	0,15
5	0,89	0,60	0,42	0,31	0,25	0,17
6	0,89	0,62	0,45	0,34	0,28	0,20
7	0,90	0,64	0,47	0,37	0,30	0,22
8	0,91	0,66	0,49	0,39	0,33	0,24
9	0,91	0,68	0,51	0,42	0,35	0,27
10	0,92	0,69	0,53	0,44	0,37	0,28

~0,10
~0,15
~0,20

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The statistical test …

Requires 6 or more measurements on workers belonging to a SEG

5.5.3 Statistical test

The appraiser shall select a statistical test to check whether the exposures of the SEG comply with the OELV. The test shall measure, with at least 70 % confidence, whether less than 5 % of exposures in the SEG exceed the OELV.

A suitable test is given in Annex F. Other tests may be used provided that they have been shown to meet the above confidence specification.

The appraiser shall make exposure measurements of the SEG according to the procedures in 5.2.2 and 5.3, in a way which meets the requirements of the test chosen. The results shall be analysed statistically according to that test.

… finds a good balance for decision errors

Requires 6 or more measurements on workers belonging to a SEG

- http://fhvmetodik.se/wp-content/uploads/2014/08/OgdenT_2012.pdf
- You can reuse measurements from the screening test; the prEN689 does not impose a time limit, but you should be confident the work situation remained unchanged since then
- Annex F using BWStat

EXAMPLE

A series of six exposure measurements is used to test compliance with an OELV of 10 ppm.

Result in ppm	ln (result)
0,8	-0,223143551
0,9	-0,105360516
1,1	0,09531018
1,4	0,336472237
4,5	1,504077397
6	1,791759469
ln(GM)	0,566519203
ln(GSD)	0,863733553

GM = 1,76 ppm ; GSD = 2,37; Arithmetic mean = 2,45 ppm.

Calculation of UR

$$U_R = \frac{\ln(10) - 0{,}566519203}{0{,}863733553} = 2{,}009$$

The U_R value is lower than the U_T value (2,187) corresponding to six exposure measurements, concluding the OELV is likely to be exceeded: **Non compliance.**

	Calculated parameters									Regression estimators					Summary				
	AM	AStdev	GM	GStdev	Shapiro-Wilk	Shapiro-WilkCrit	U	UCrit95%,70%	UTL95%,70%	GMGraph (intercept)	GStdevGraph (slope)	UGraph	UCritGraph95%,70%	UTLGraph95%,70%	number > OEL	Lognormal	Compliant95%,70%	df (number -1)	CompliantGraph95%,70%	df (number > LoQ -1)
Group	2,45	2,23	1,76	2,37	0,84	0,79	2,01	2,19	11,65	1,76	2,40	1,99	2,19	11,92	0	1	0	5	0	5

$U_R < U_T$

E:ok F:inkl

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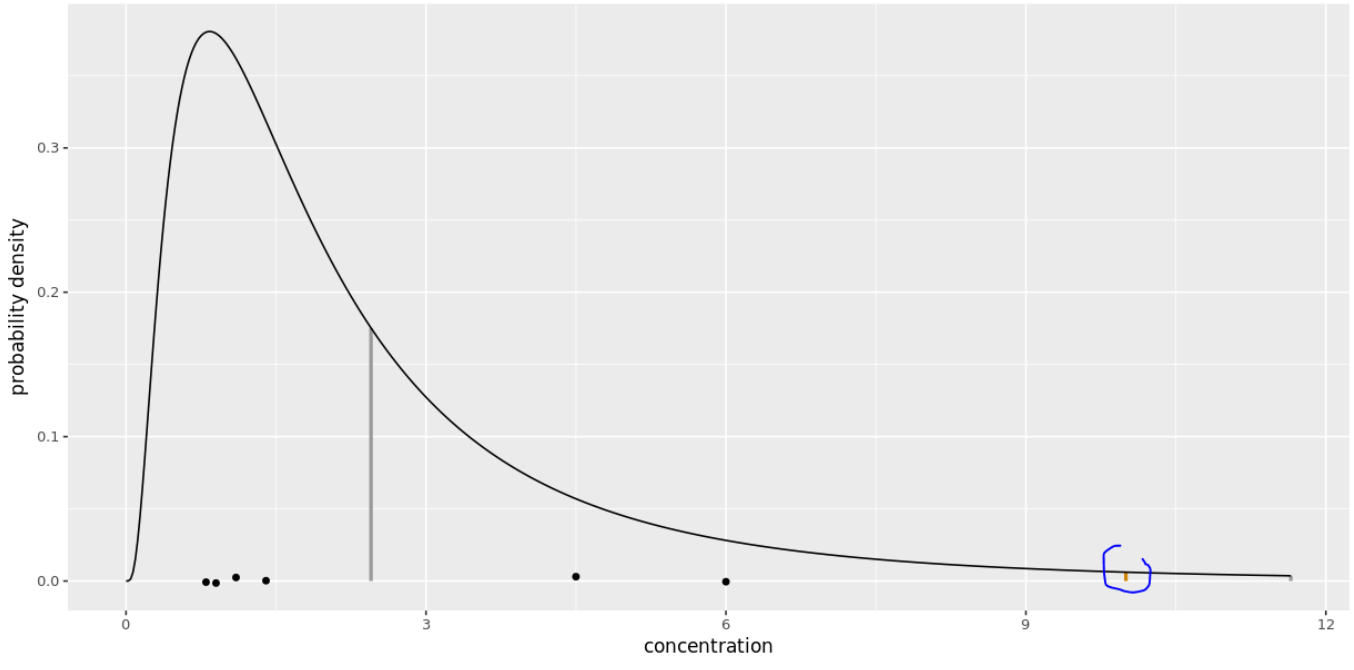
...or BWStat Web

e.g. for comparing Ucalc / Uregr with Ucrit

- BWStat Web annex F

Conclusion: More than 5 samples!
GM (calc): 1.762
GSD (calc): 2.372
GM (regr): 1.762
GSD (regr): 2.397
Ucrit value: 2.187
Ucalc value: 2.01
Uregr value: 1.986
Conclusion (calc): non-compliance
Conclusion (regr): non-compliance

value	worker	date	detect
0.80	f	d	TRUE
0.90	f	d	TRUE
1.10	f	d	TRUE
1.40	f	d	TRUE
4.50	f	d	TRUE
6.00	f	d	TRUE



The statistical test …

Requires an approach for handling <LOQ

If one or more of the exposure measurements are below the limit of quantification (LOQ), and the statistical test selected involves use of geometric (GSD) or standard (SD) deviations and/or geometric (GM) or arithmetic (AM) means, then the values below the LOQ shall be treated in a way which produces a reliable result. Methods are described in Annex H for a case where a minority of results are <LOQ.

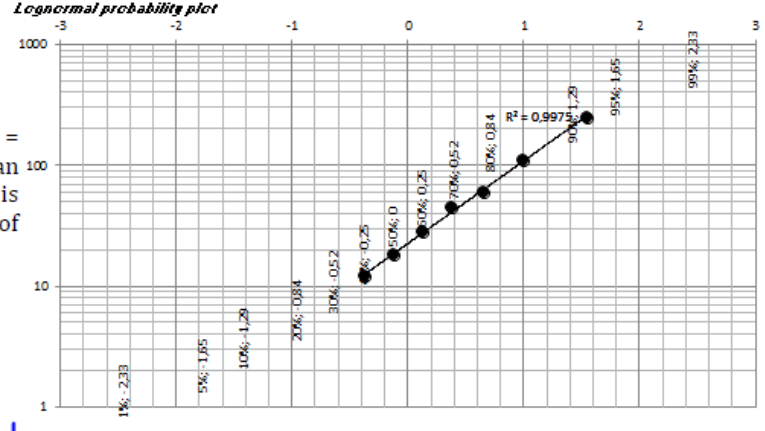
Applying such tests to the exposure measurements assumes that the measurements are log-normally distributed (see Annex E). This is usually true at least approximately, and it is unusual to have enough measurements to show statistically that it is not true.

… with <LOQ results can be done automated or manually

Requires an approach for handling <LOQ

- You can automate this (eg in a spreadsheet), but it's implemented already in Hyginist, Altrex, NDExpo and of course BWStat

The regressi… …cient (in this case 1,5739) is the natural log of the GSD of the distribution, so GSD = exp(1,5739) = 4,8 a…pproximat…y, and the intercept 3,1129 is the natural log of the geometric mean exposure: GM = exp(3,1129) = 22,5 ppm. This can be checked against Figure H.1, because the GM is equal to the median for a logn…rmal distribution, and the geometric standard deviation is the ratio of the concentrations at the 0,841 and 0,50 fraction points.



ROS+ SUB

H

	Calculated parameters									Regression estimators					Summary					
	AM	AStdev	GM	GStdev	Shapiro-Wilk	Shapiro-WilkCrit	U	UCrit95%,70%	UTL95%,70%	GMGraph (intercept)	GStdevGraph (slope)	UGraph	UCritGraph95%,70%	UTLGraph95%,70%	number > OEL	Lognormal	Compliant95%,70%	df (number - 1)	CompliantGraph95%,70%	df (number > LoQ - 1)
Group	53,64	76,57	22,42	4,32	0,98	0,84	2,59	2,01	421,98	22,49	4,83	2,41	2,01	527,66	0	1	1	9	1	6

...or BWStat Web

e.g. for choosing an impution method

- BWStat Web annex H

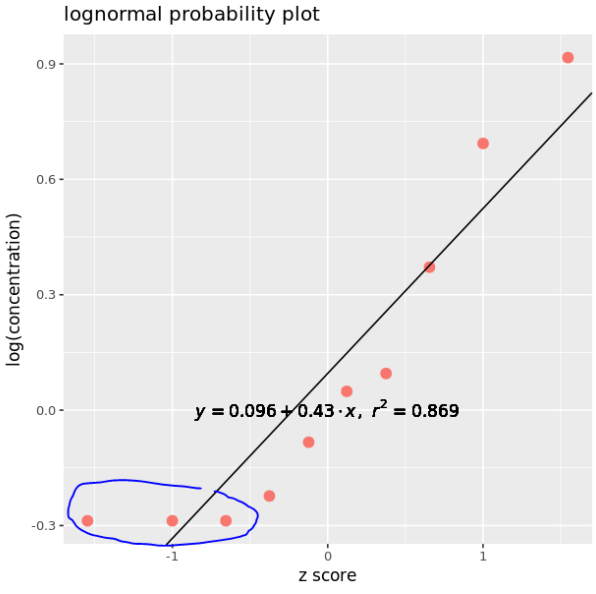
Choose imputation method:

none

none
BWStat (ROS)
NDExpo (Robust ROS)

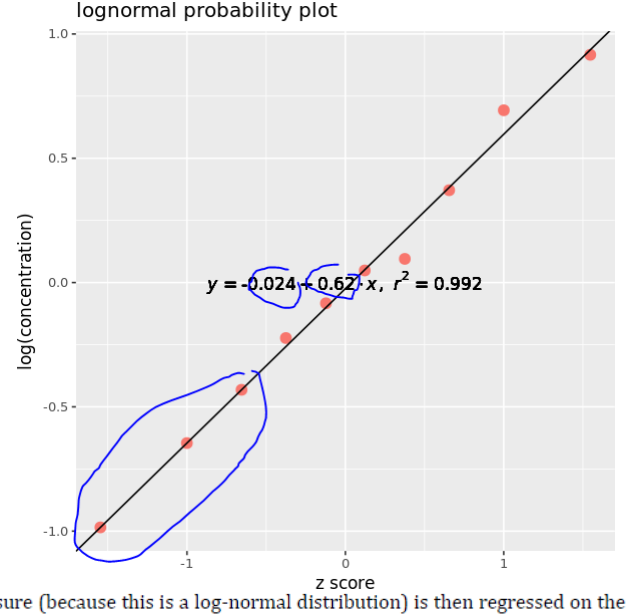
Conclusion: More than 5 samples!
GM (calc): 1.1
GSD (calc): 1.541
GM (regr): 1.1
GSD (regr): 1.535
Ucrit value: 2.005
Ucalc value: 1.006
Uregr value: 1.015
Conclusion (calc): non-compliance
Conclusion (regr): non-compliance

value	worker	date	detect
0.75	h	d	FALSE
0.75	h	d	FALSE
0.75	h	d	FALSE
0.80	h	d	TRUE
0.92	h	d	TRUE
1.05	h	d	TRUE
1.10	h	d	TRUE
1.45	h	d	TRUE
2.00	h	d	TRUE
2.50	h	d	TRUE



Conclusion: More than 5 samples!
GM (calc): 0.976
GSD (calc): 1.797
GM (regr): 0.976
GSD (regr): 1.861
Ucrit value: 2.005
Ucalc value: 0.947
Uregr value: 0.894
Conclusion (calc): non-compliance
Conclusion (regr): non-compliance

value	worker	date	detect
0.37	h	d	FALSE
0.52	h	d	FALSE
0.65	h	d	FALSE
0.80	h	d	TRUE
0.92	h	d	TRUE
1.05	h	d	TRUE
1.10	h	d	TRUE
1.45	h	d	TRUE
2.00	h	d	TRUE
2.50	h	d	TRUE



The natural log (ln) of the exposure (because this is a log-normal distribution) is then regressed on the *Z*-score for the seven points above LOQ, using a least-squares linear regression technique. This is explained in any statistics textbook [12] and is implemented in many calculators and statistics packages. The result is shown in Figure H.2. The fitted regression line in this case is

$$\ln(\text{exposure}) = 0{,}619\ Z - 0{,}0248 \qquad \text{(H.2)}$$

The regression coefficient (in this case 0,619) is the natural log of the GSD of the distribution, so GSD = exp(0,619) = 1,86 approximately, and the intercept -0,0248 is the natural log of the geometric mean exposure: GM = exp(-0,0248) = 0.976 mg/m³. The calculation method is more accurate than the graphical method, but the graphical method can easily be used as a rough check of the calculation.

Provikmo
ADMB preventie

BWStat

Where to find BWStat?

- BWStat (excel version): https://www.bsoh.be/?q=en/node/67
- BWStat (web version, for testing purposes only): https://www.bsoh.be/?q=nl/bwstat

Tom Geens

tom.geens@provikmo.be