Workshop BW_Statv1.
Het Excel tool bij de NVvA-BOHS compliance testing guidance

NVvA Symposium

18 april 2013 Workshop I

11:20 – 12:50

Theo Scheffers, Tom Geens,
Trevor Ogden , John Ingle

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Contents

- **Introduction (Trevor at NVvA /John at BOHS)**
- Features (Tom)
- Exercise (Theo)
- Future (Tom)
- Contact information

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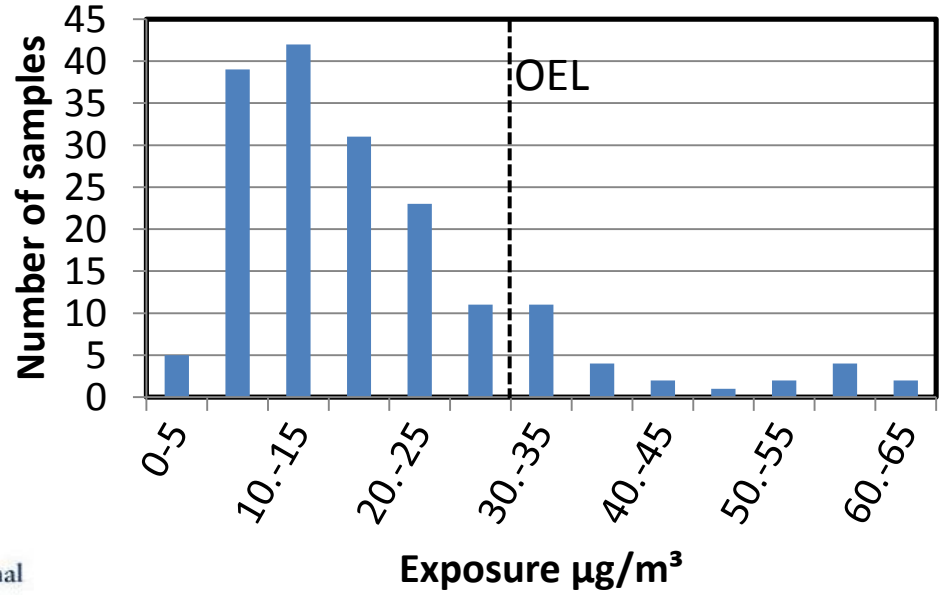
Testing compliance with Occupational Exposure Limits – Introduction to the BOHS-NVvA guidance.

Trevor Ogden
formerly BOHS co-chair BOHS-NVvA Working Group. (NVvA co-chair was Hans Kromhout)



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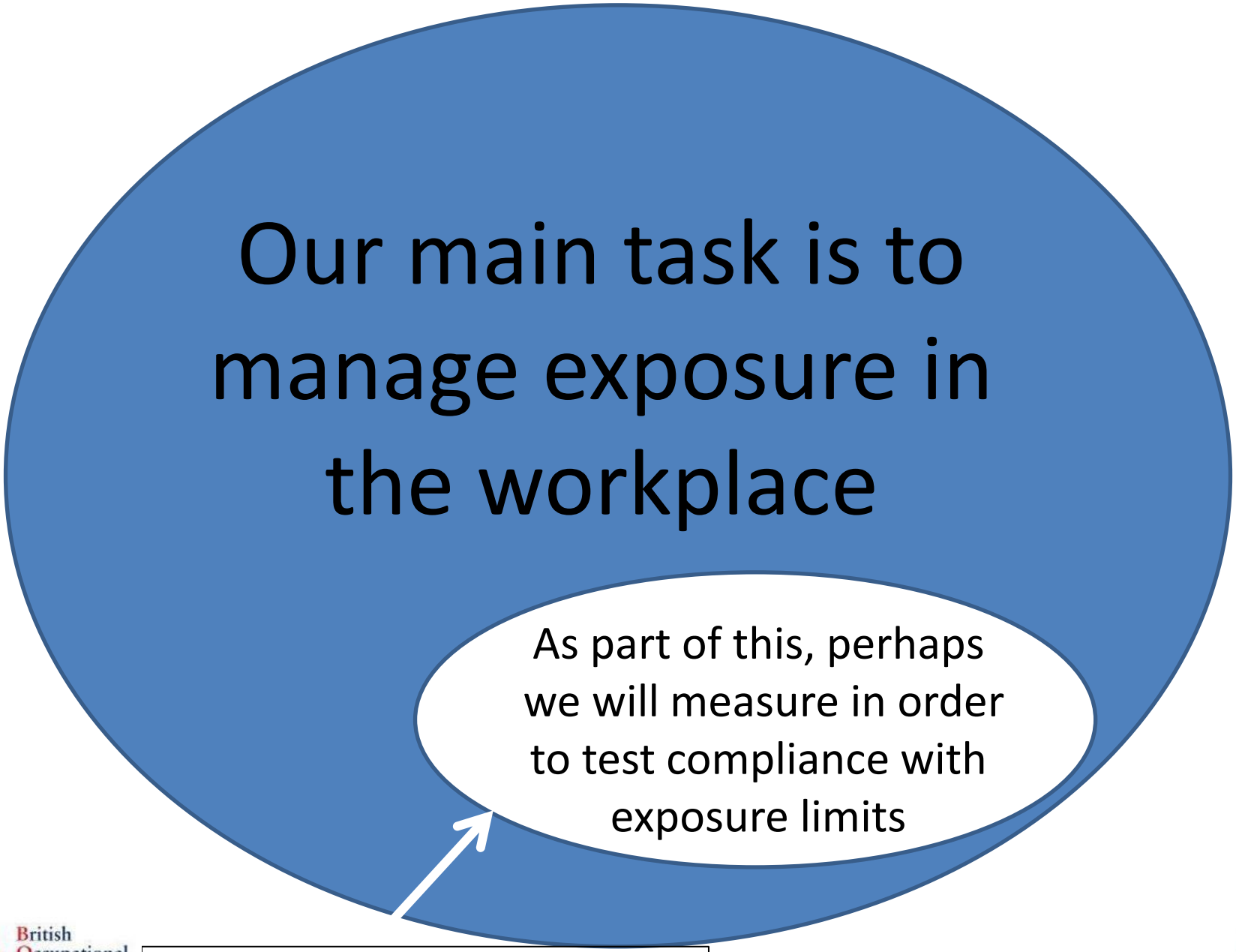

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This is the bit I am talking about

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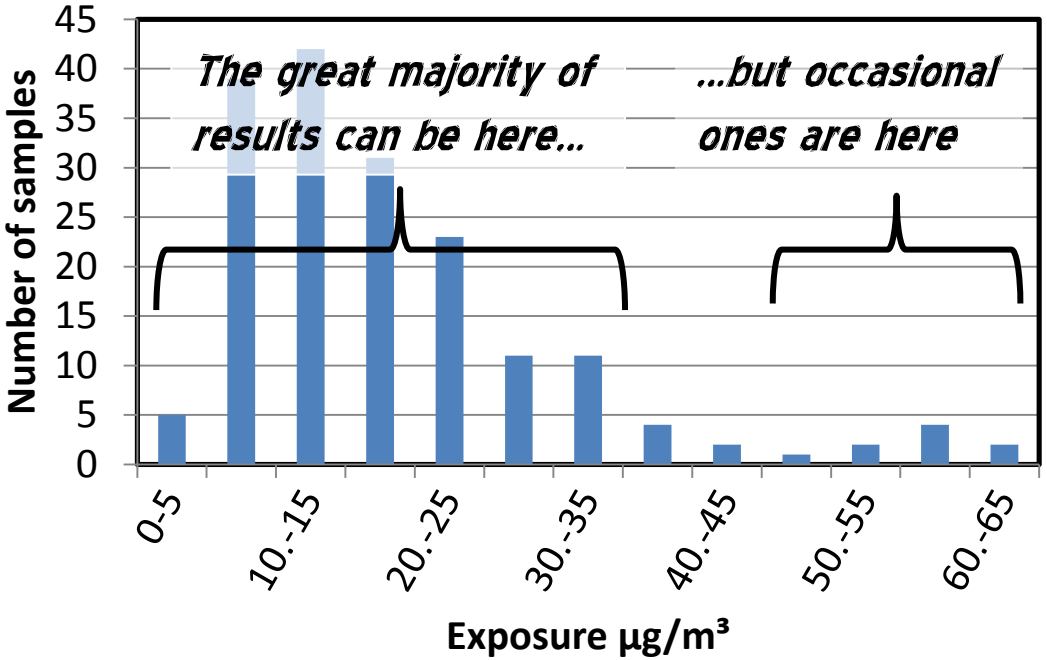
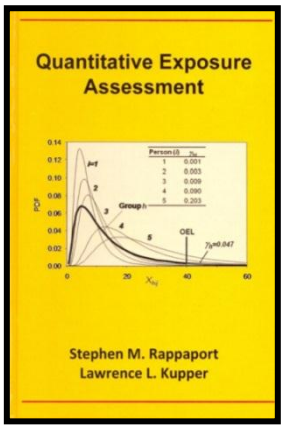
Problem 1: There is usually no sharp upper limit to exposure



This example of 177 personal lead exposures comes from *Rappaport and Kupper, 2008, "Quantitative Exposure Assessment", ISBN 978-0-9802428-0-5, www.lulu.com*



- *The exposure level comes from the interaction of many variables,*
- *there is always a chance that these will combine in a way which produces exceptional exposure,*
- *there seems no way of preventing these occasional high values (unless you totally separate worker and source)*

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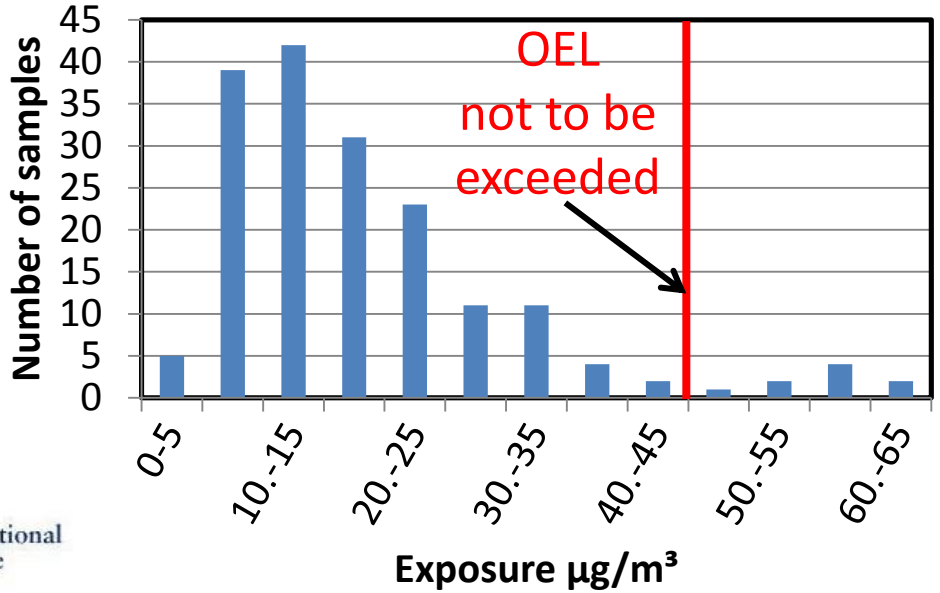
Exposure limits used to be ***guidance*** for professionals, but regulators treat OELs as sharp dividing lines :

"Exposure shall not exceed the limit value..."

- EU Carcinogens Directive Art 5(4)

"where an occupational exposure limit value...has been exceeded, the employer shall immediately take steps…"

- EU Chemical Agents Directive Art 6(5)



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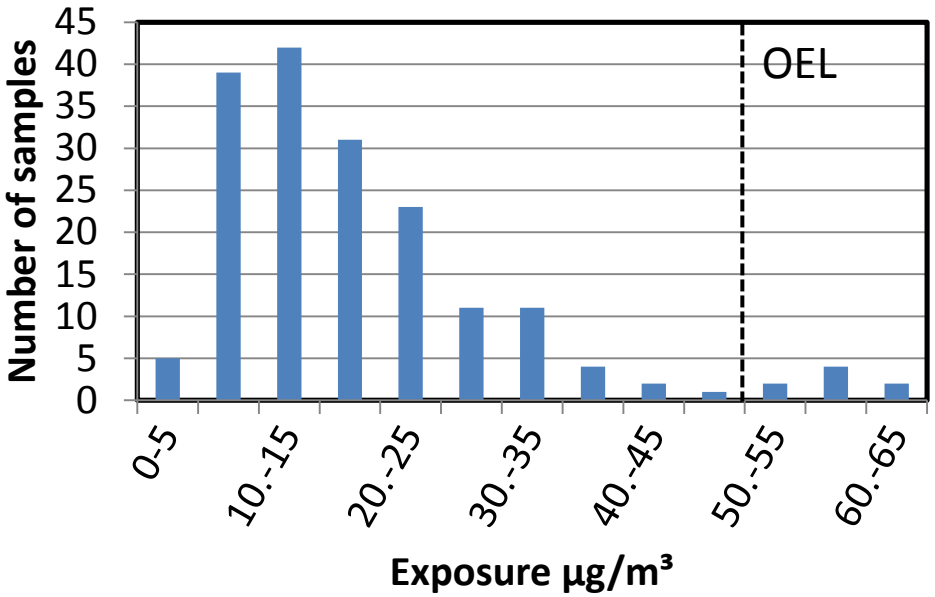

Do I comply?

An enforcer only needs one valid measurement over the OEL to prove you do not comply.

But no matter how many measurements a hygienist has <OEL, how does he or she know that the next one will not be >OEL?

We need an agreed strategy – how many measurements do you need to have < OEL, and how far below the OEL, before you can assume that you comply?

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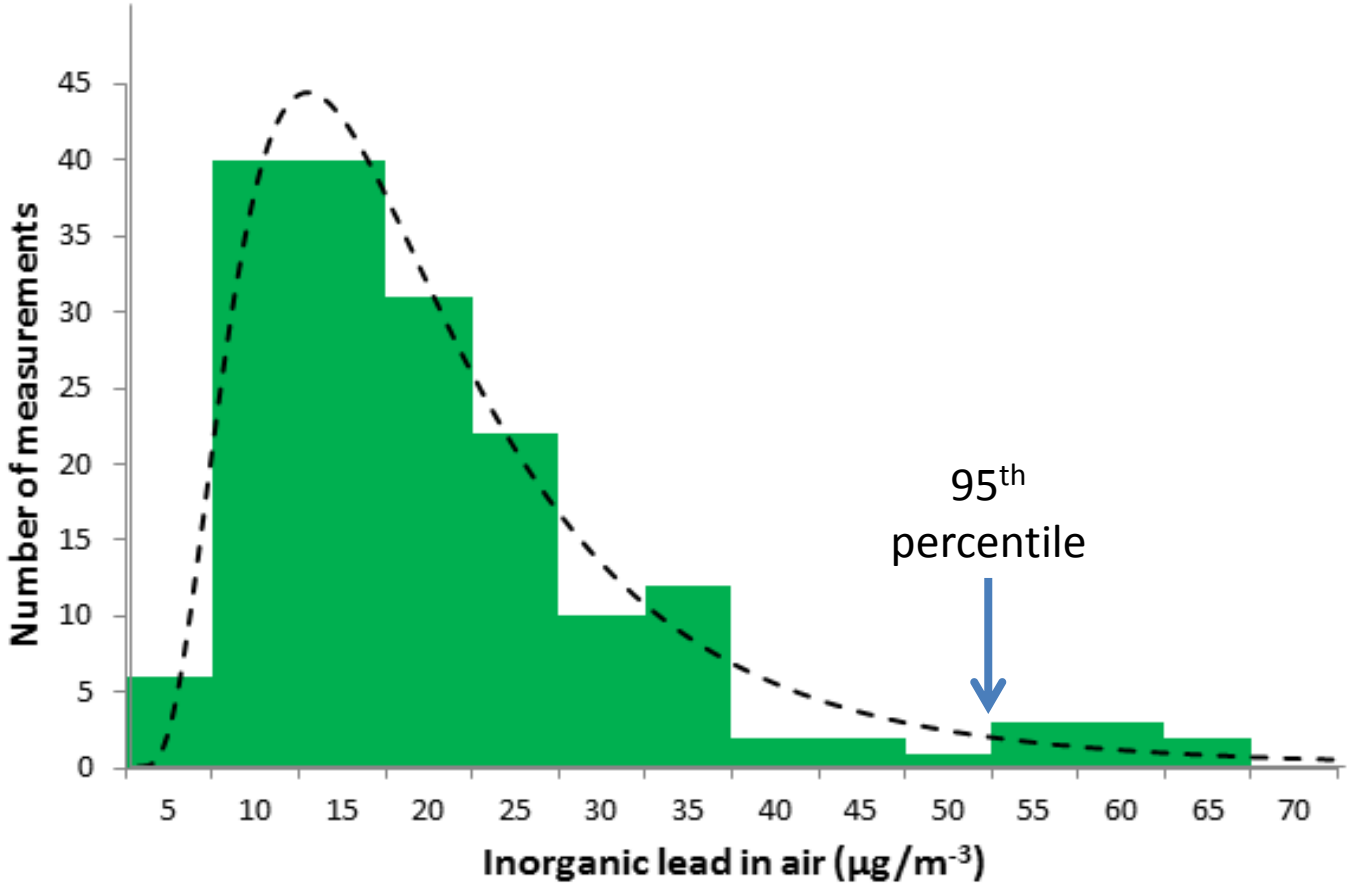
A common approach is to fit a log-normal curve to the data and say that the exposure complies if >95% of distribution is <OEL



The histogram is Cope et al's measurements of lead in air. The curve is the lognormal distribution with the same geometric mea and geometric standard deviation as the measurements.

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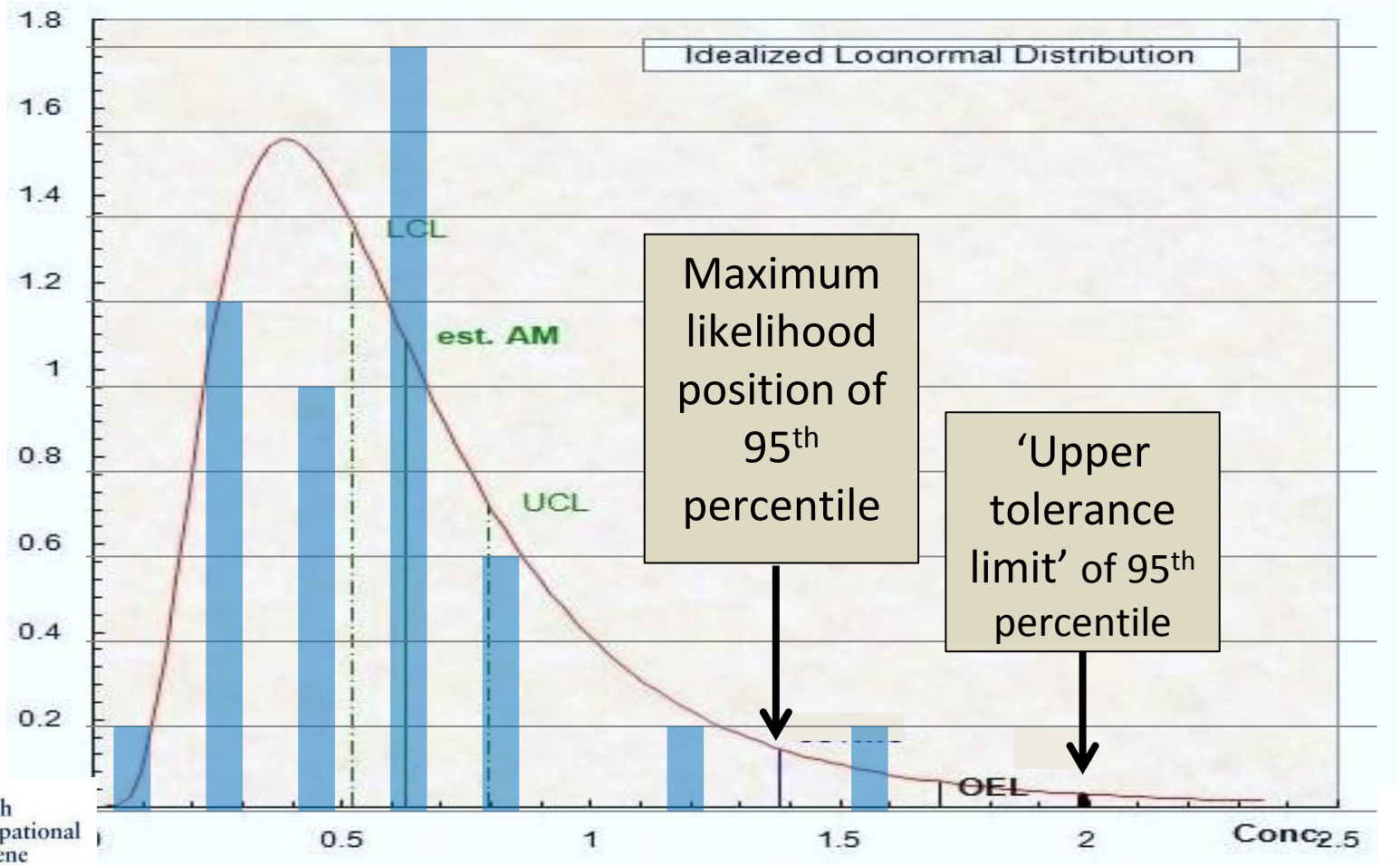
But unfortunately if you fit a log-normal curve to just a few measurements, there is uncertainty in the best-fit curve, and therefore uncertainty in the position of the real 95th percentile.

So it looks as you will need a large number of measurements to be sure that the 95th percentile is < the occupational exposure limits.



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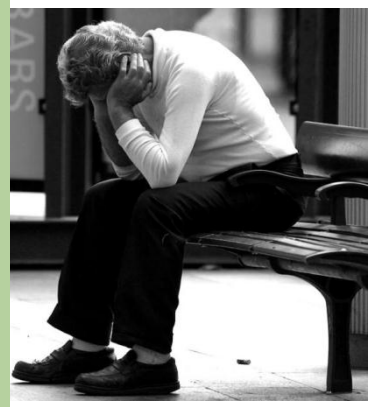
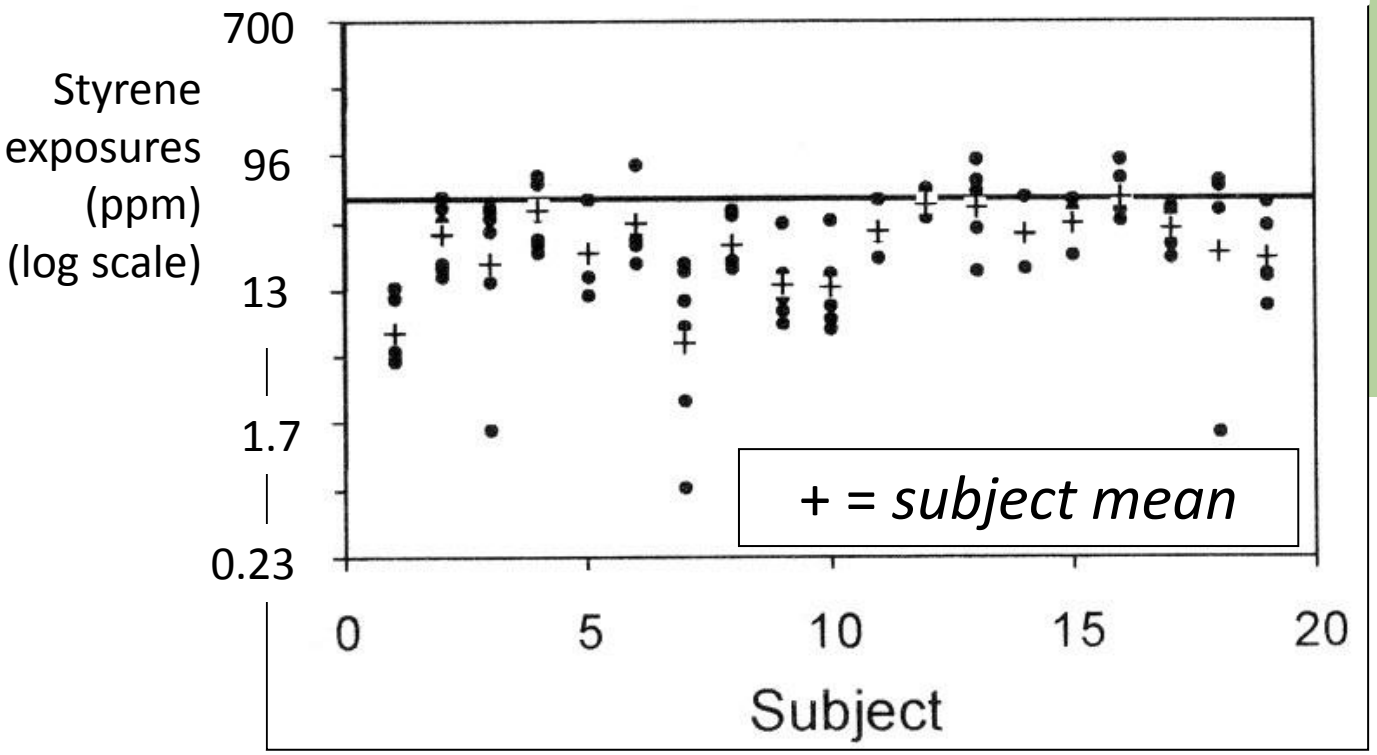
There is another problem. There are reports of big variation in exposure between workers doing the same job





An OEL applies to each individual worker!

EXPOSURES OF 19 SUBJECTS SPRAYING OR LAMINATING IN BOAT MANUFACTURE.

From Rappaport and Kupper, 2008, "Quantitative Exposure Assessment", ISBN 978-0-9802428-0-5, www.lulu.com

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Three problems:

(1) Regulations often define OELs as sharp limits which must not be exceeded, but exposure doesn't behave that way

(2) You can use the 95th percentile, but you need a lot of sampling to determine it accurately

(3) OELs apply to every individual, but exposure on the same job can vary a lot with individual, even, apparently, within a Similarly Exposed Group

Some past attempts at designing strategies

1977: Leidel et al, "Occupational Exposure Sampling Strategy Manual", NIOSH.

1993: BOHS Technical Guide 11, "Sampling strategies for airborne contaminants in the workplace"

1995: European Standard EN689, "Workplace atmospheres – Guidance for the assessment of exposure by inhalation to chemical agents for comparison with limit values and measurement strategy"

In 2007 the Dutch and British occupational hygiene societies decided to produce new joint guidance.

2009: French regulation. Based on computer simulations, it is most efficient to use the 70% UCL of the 95th percentile

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Structure of the BOHS/NVvA guidance:

(1) Form Similarly Exposed Groups (SEGs)

(2) Preliminary test **Three measurements per SEG** to eliminate groups that obviously comply or obviously fail.

(3) Test *group compliance:* **≥6 more measurements per SEG**

Based on ≥ 9m measurements, the group complies if, with 70% confidence, <5% of the exposures in the SEG exceed the OEL

(4) Do analysis of variance to see if individual differences are important.

(5) If so, test *individual compliance*
80% of the workers in the SEG must have <5% of their exposures >OEL

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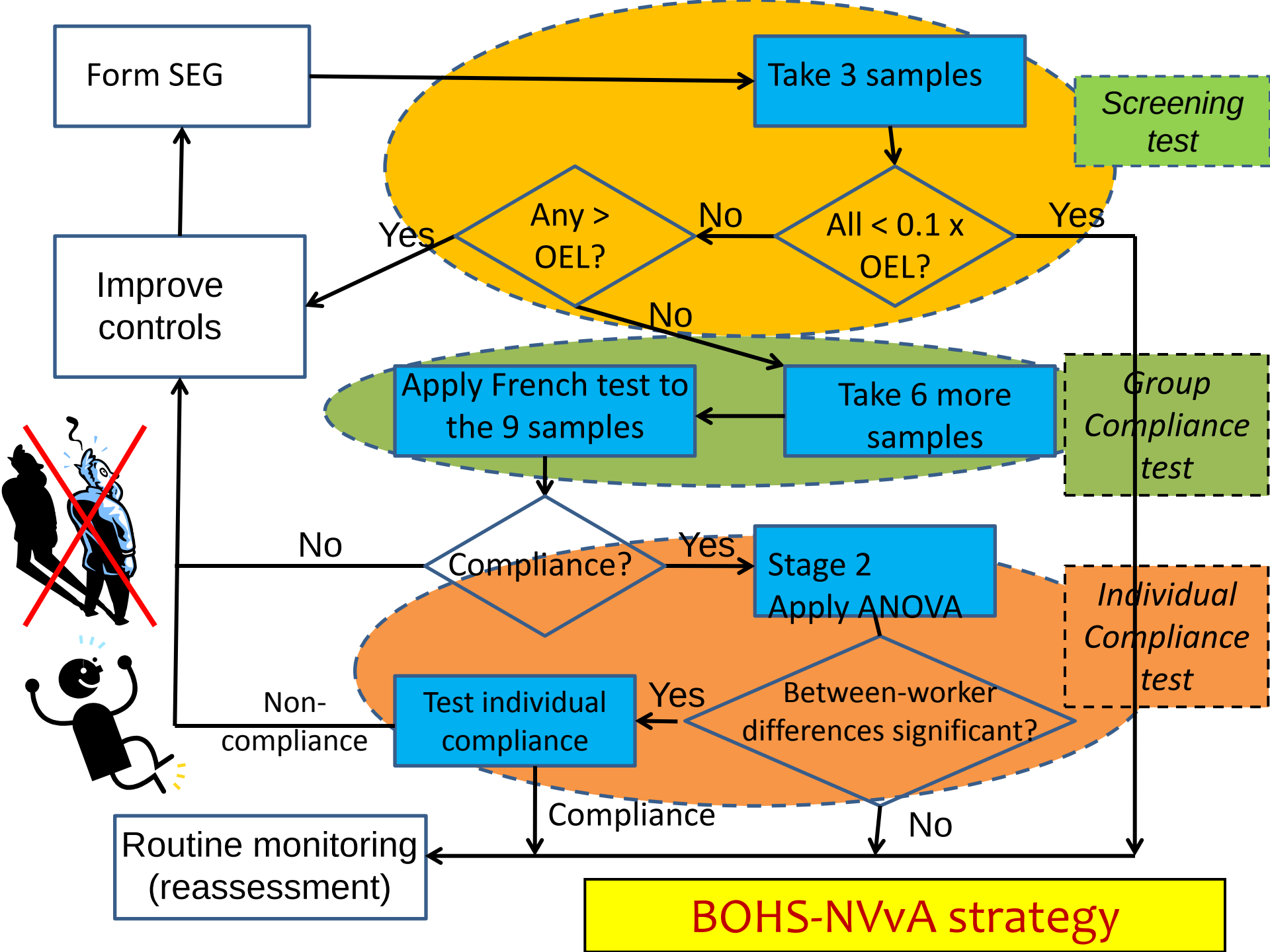
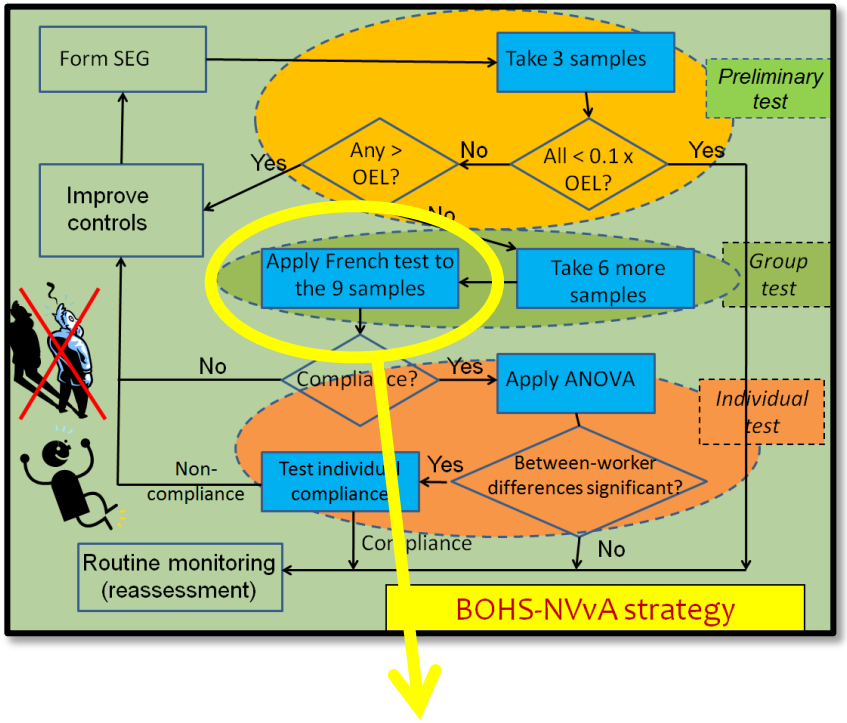
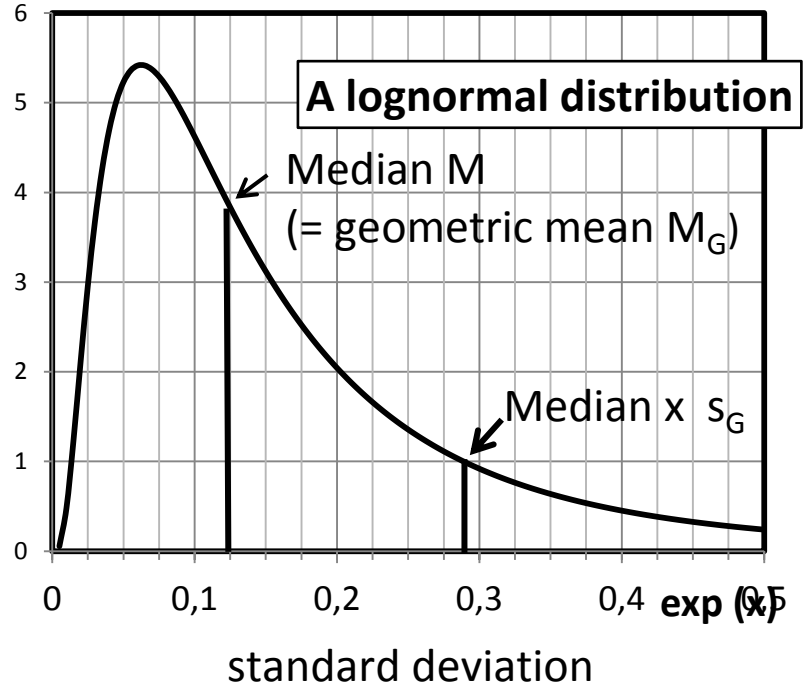

Form SEG
Take 3 samples
Screening test
All < 0.1 x OEL?
No
Yes
Any > OEL?
Yes
No
Improve controls
Apply French test to the 9 samples
Take 6 more samples
Group Compliance test
No
Compliance?
Yes
Stage 2 Apply ANOVA
Individual Compliance test
Between-worker differences significant?
Yes
Test individual compliance
Non-compliance
Compliance
No
Routine monitoring (reassessment)
BOHS-NVvA strategy





Group compliance test (French test):

(1) Calculate parameter U

$$U = [\log(OEL) - \log M_G] / \log s_G$$

Geometric mean

Geometric standard deviation

of the (at least) nine measurements on the SEG

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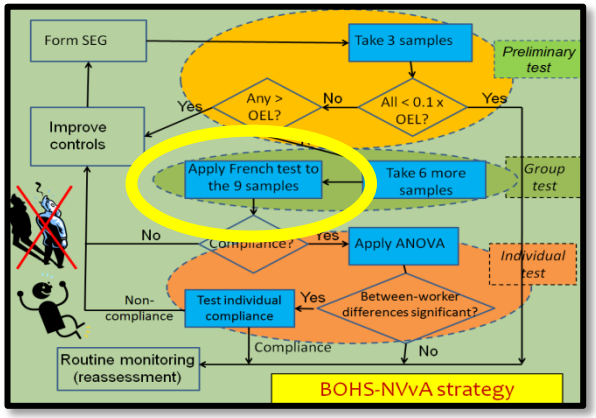
Group compliance test: $U = [\log(OEL) - \log M_G] / \log s_G$

(2) Compare the value of U obtained with limiting values in a Table

Number of exposure measurements	Limiting value of U
9	2.035
10	2.005
11	1.981
12	1.961
13	1.944
14	1.929
15	1.917



If (U obtained) < (U in table) then OEL is not complied with

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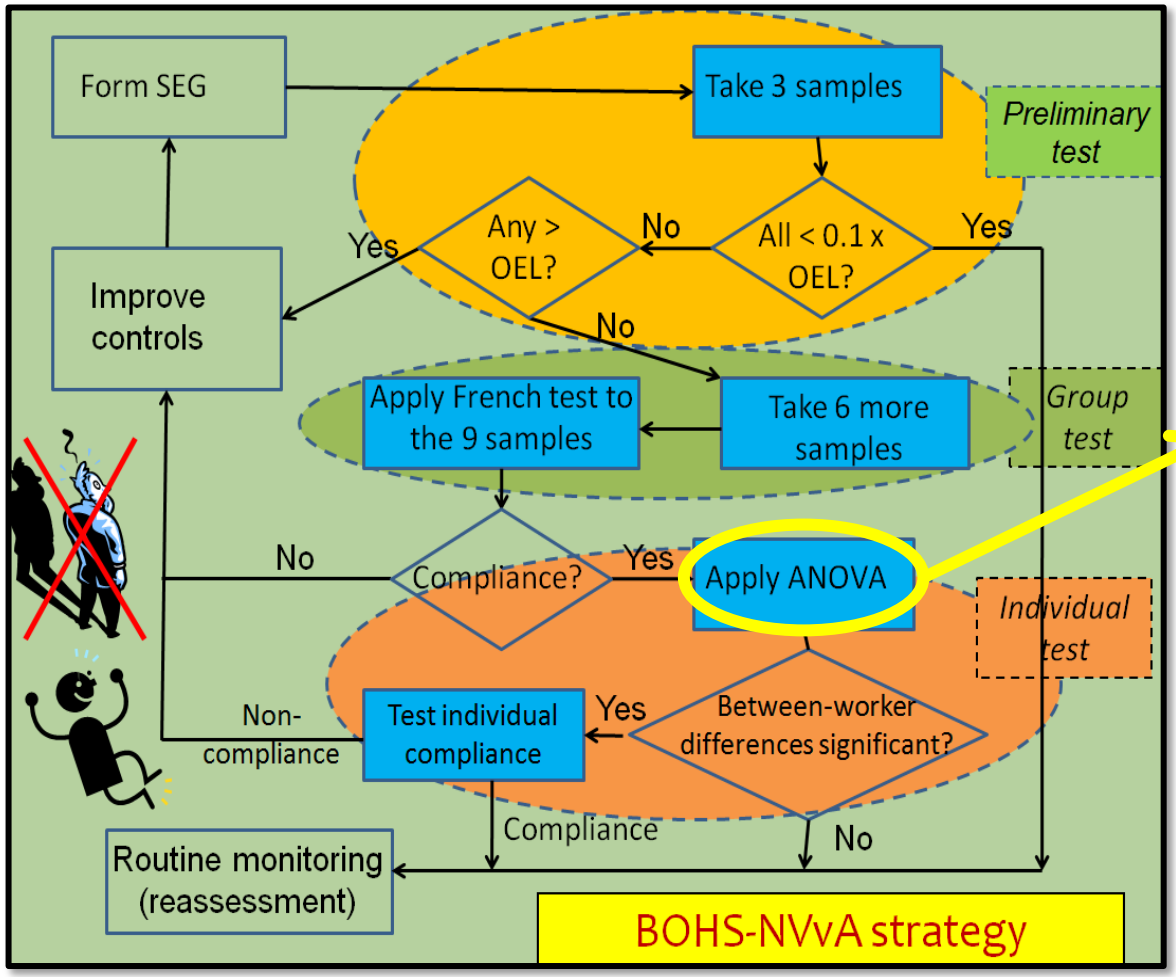

Tests how much of the variation between exposures is due to variation between workers (eg due to methods of work) and how much is due to other causes

If inter-worker variance is less than 20% of total variance, you don't have to test individual compliance

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Individual compliance test:

Calculate

$$H = [\log(OEL) - (\log M_G + 1.645\, s_w)] / s_b$$

Geometric mean

Within-worker standard deviation

Between-worker standard deviation

H is a point in the distribution of exposures. The fraction of the distribution which is more than H must be <20%

A pass means that at least 80% of the workers in the SEG have <5% of their exposures >OEL

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Confused?

It's OK – all you need is Tom and Theo's spreadsheet!

The guidance document is on the NVvA and BOHS websites

More details of the underlying computer simulations and development of the guidance:
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

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The worksheet

- Downloadable from http://www.tsac.nl/websites.html
- Compatible with Excel 2003,2007 and 2010
- No more excuses for not using the guidance
  - No extra installation of software, universal excel application
  - Macro-free, no need to enable macro's
  - No extra programming, easy input & output (beware: GIGO!)

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Startup screen

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

Tab Start and Manual

Tab Data

Tab Report

Tab Examples

Manual

1.	**Select your language:**	**English**	
2.	**Enter the name of the substance:**	**Cotton dust**	
3.	**Enter the units of measurement**	**mg/m³**	
4.	**Enter the occupational exposure limit (O**	**1,70**	**mg/m³**
5.	**Enter the lower limit of quantification (LoQ=accuracy)** **Also to be read out from the lognormal probability plo**	**0,17**	**mg/m³**
6.	**Optional input of the analytical lower detection limit (L**	**0,04**	**mg/m³**

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 andflowchart 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)

Disclaimer

Start & Manual | Data | Report | Examples

Tab Start & Manual

Testing Compliance with Occupational Exposure Limits for Airborne Substances, Sept. 2011
BW_Stat v1.0

	Manual			
1.	**Select your language:**		**English**	
2.	**Enter the name of the substance:**		**Cotton dust**	
3.	**Enter the units of measurement:**		**mg/m³**	
4.	**Enter the occupational exposure limit (OEL):**		**1,70**	**mg/m³**
5.	**Enter the lower limit of quantification (LoQ=accuracy). Typically three times the LoD. Also to be read out from the lognormal probability plot:**		**0,17**	**mg/m³**
6.	**Optional input of the analytical lower detection limit (LoD=accuracy):**		**0,04**	**mg/m³**
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9.	**Use BW_Stat only after reading the Disclaimer right to the flowchart.**			
	Fig.5. Flowchart of the process (from the guidance, page 19)			
		Disclaimer		

Start & Manual | Data | Report | Examples

Tab Data: typing

- When entering data manually:
  - Use Date identifiers
  - Use Worker identifiers
  - Enter measurement outcomes as they appear on the lab report, associate them with valid identifiers
  - Not doing so will result in a visual warning

	A	B	C	D	E	F
1	OEL	1,7	2 ker1	worker2	worker3	worker4
2		1	Greg	Joe	Chloe	
3	Date1	Mon	0,16	0,51	0,18	
4	Date2	Tue	0,38	0,60		
5	Date3	Wed	0,20	0,35	3	
6	Date4	Thur	0,44	0,70	0,65	4
7	Date5					5,00

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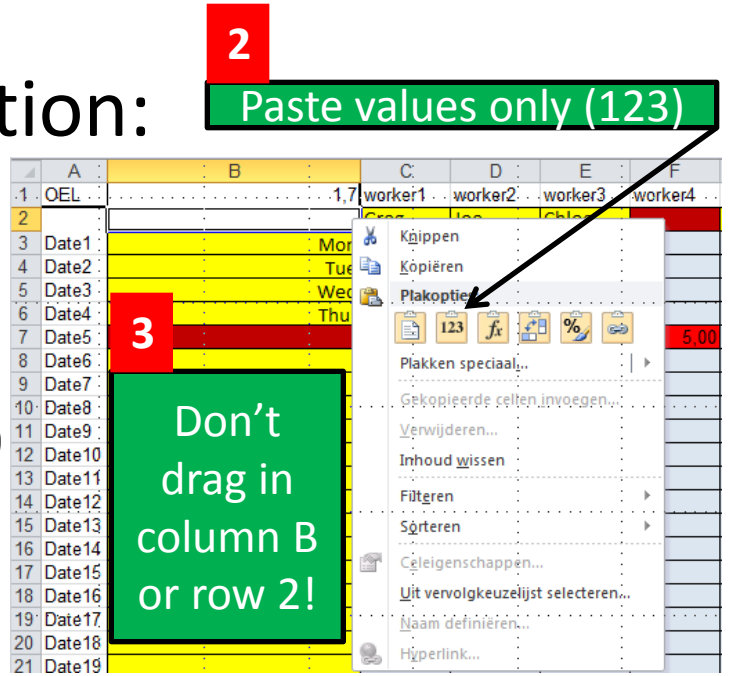
Tab Data: copy paste

- When using copy-paste function:
  - Paste special in B2 (right click)
  - Paste values (123), no layout!
  - Don't use drag in IDs (cB & r2)
  - Not doing so will inevitably destroy some functionalities



	A	B	C	D	E	F
1	OEL	1,7	worker1	worker2	worker3	worker4
2		Paste here	Greg	Joe	Chloe	
3	Date1	Mon	0,16	0,51	0,18	
4	Date2	Tue	0,38	0,60		
5	Date3	Wed	0,20	0,35		
6	Date4	Thur	0,44	0,70	0,65	
7	Date5					5,00

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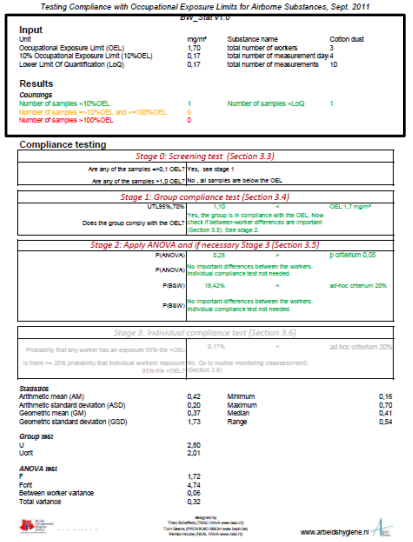
Tab Report

- Input and Results section with basic *countings* (above)



Testing Compliance with Occupational Exposure Limits for Airborne Substances, Sept. 2011
BW_Stat v1.0

Input

Unit	mg/m³	Substance name	Cotton dust
Occupational Exposure Limit (OEL)	1,70	total number of workers	3
10% Occupational Exposure Limit (10%OEL)	0,17	total number of measurement day:	4
Lower Limit Of Quantification (LoQ)	0,17	total number of measurements	10

Results

Countings

Number of samples <10%OEL	1	Number of samples <LoQ	1
Number of samples =>10%OEL and <=100%OEL	9		
Number of samples >100%OEL	0		

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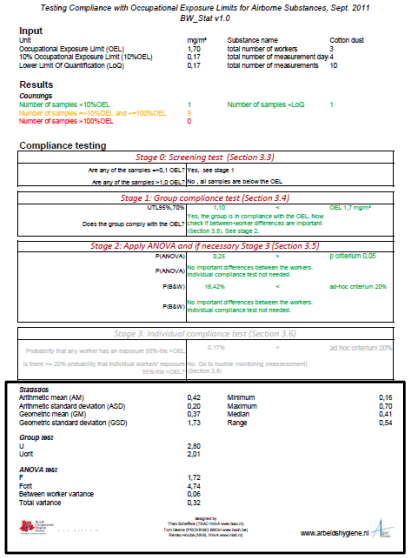
Tab Report

- Results section *statistics, group test, ANOVA* (below)



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

Unit	mg/m³	Substance name	Cotton dust
Occupational Exposure Limit (OEL)	1,70	total number of workers	3
10% Occupational Exposure Limit (10%OEL)	0,17	total number of measurement day-1	4
Lower Limit Of Quantification (LoQ)	0,17	total number of measurements	10

Results

Countings

Number of samples <10%OEL	1	Number of samples <LoQ	1
Number of samples >=10%OEL and <=100%OEL	9		
Number of samples >100%OEL	0		

Compliance testing

Stage 0: Screening test (Section 3.3)

Are any of the samples >=0,1 OEL?	Yes, see stage 1
Are any of the samples >1,0 OEL?	No , all samples are below the OEL

Stage 1: Group compliance test (Section 3.4)

UCL95(LOG)	1,10	<	OEL 1,7 mg/m³
Does the group comply with the OEL?	Yes, the group is in compliance with the OEL. Now check if between-worker differences are important (Section 3.5). See stage 2.		

Stage 2: Apply ANOVA and if necessary Stage 3 (Section 3.5)

P(ANOVA)	0,29	>	p criterium 0,05
P(ANOVA)	No important differences between the workers. Individual compliance test not needed.		
P(BiW)	18,42%	<	ad-hoc criterium 20%
P(BiW)	No important differences between the workers. Individual compliance test not needed.		

Stage 3: Individual compliance test (Section 3.6)

Probability that any worker has an exposure 95%-tile >OEL	0,176%	<	ad hoc criterium 20%
Is there >= 20% probability that individual workers' exposure 95%-tile >OEL?	No. Go to routine monitoring (reassessment) (Section 3.8)		

Statistics

Arithmetic mean (AM)	0,42	Minimum	0,16
Arithmetic standard deviation (ASD)	0,20	Maximum	0,70
Geometric mean (GM)	0,37	Median	0,41
Geometric standard deviation (GSD)	1,73	Range	0,54

Group test

U	2,80
Ucrit	2,01

ANOVA test

F	1,72
Fcrit	4,74
Between worker variance	0,06
Total variance	0,32

designed by
Theo Scheffers (TSAC NVvA www.tsac.nl)
Tom Geens (PROVIKMO BSOH www.bsoh.be)
Remko Houba (NKAL NVvA www.nkal.nl)

www.arbeidshygiene.nl

Statistics

Arithmetic mean (AM)	0,42	Minimum	0,16
Arithmetic standard deviation (ASD)	0,20	Maximum	0,70
Geometric mean (GM)	0,37	Median	0,41
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Group test

U	2,80
Ucrit	2,01

ANOVA test

F	1,72
Fcrit	4,74
Between worker variance	0,06
Total variance	0,32

designed by
Theo Scheffers (TSAC NVvA www.tsac.nl)
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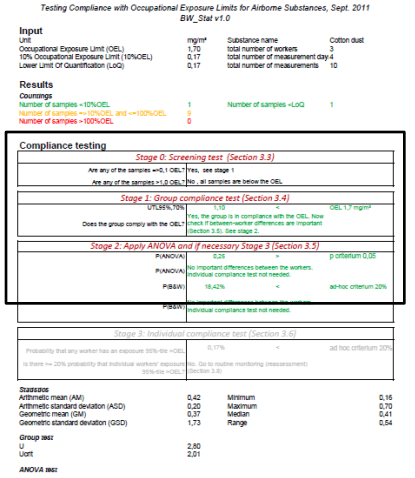
Remko Houba (NKAL NVvA www.nkal.nl)

www.bohs.org

www.arbeidshygiene.nl

Tab Report

- Results section *compliance testing* (middle)



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BW_Stat v1.0

Input

Unit	mg/m³	Substance name	Cotton dust
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Results

Countings

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Number of samples >100%OEL	0		

Compliance testing

Stage 0: Screening test (Section 3.3)

Are any of the samples =>0,1 OEL?	Yes, see stage 1
Are any of the samples >1,0 OEL?	No , all samples are below the OEL

Stage 1: Group compliance test (Section 3.4)

UTL95%,70%	1,10	<	OEL 1,7 mg/m³
Does the group comply with the OEL?	Yes, the group is in compliance with the OEL. Now check if between-worker differences are important (Section 3.5). See stage 2.		

Stage 2: Apply ANOVA and if necessary Stage 3 (Section 3.5)

P(ANOVA)	0,25	>	p criterium 0,05
P(ANOVA)	No important differences between the workers. Individual compliance test not needed.		
P(B&W)	18,42%	<	ad-hoc criterium 20%
P(B&W)	No important differences between the workers. Individual compliance test not needed.		

Stage 3: Individual compliance test (Section 3.6)

Probability that any worker has an exposure 95%-tile >OEL	0,17%	<	ad hoc criterium 20%
Is there >= 20% probability that individual workers' exposure 95%-tile >OEL?	No. Go to routine monitoring (reassessment) (Section 3.8)		

Statistics

Arithmetic mean (AM)	0,42	Minimum	0,16
Arithmetic standard deviation (ASD)	0,20	Maximum	0,70
Geometric mean (GM)	0,37	Median	0,41
Geometric standard deviation (GSD)	1,73	Range	0,54

Group test

U	2,80
Ucrit	2,01

ANOVA test

Compliance testing

Stage 0: Screening test (Section 3.3)

Are any of the samples =>0,1 OEL?	Yes, see stage 1
Are any of the samples >1,0 OEL?	No , all samples are below the OEL

Stage 1: Group compliance test (Section 3.4)

UTL95%,70%	1,10	<	OEL 1,7 mg/m³
Does the group comply with the OEL?	Yes, the group is in compliance with the OEL. Now check if between-worker differences are important (Section 3.5). See stage 2.		

Stage 2: Apply ANOVA and if necessary Stage 3 (Section 3.5)

P(ANOVA)	0,25	>	p criterium 0,05
P(ANOVA)	No important differences between the workers. Individual compliance test not needed.		
P(B&W)	18,42%	<	ad-hoc criterium 20%
P(B&W)	No important differences between the workers. Individual compliance test not needed.		

Stage 3: Individual compliance test (Section 3.6)

Probability that any worker has an exposure 95%-tile >OEL	0,17%	<	ad hoc criterium 20%
Is there >= 20% probability that individual workers' exposure 95%-tile >OEL?	No. Go to routine monitoring (reassessment) (Section 3.8)		

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Nederlandse Vereniging voor Arbeidshygiëne

Contents

- Introduction (Trevor at NVvA /John at BOHS)
- Features (Tom)
- **Exercise (Theo)**
- Future (Tom)
- Contact information

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Example n-Hexane

- SEG: workers extracting vegetable oils
- n-Hexane PAS $TWA_{8\ hrs}$ measurements
- Legal limit in most EU countries (WEL/IOLV):
  - 72 mg/m^3/8 hours
- Sampling methods
  - Workplace Measurement Method Summaries 2nd IOELV List : HSL/2002/23
  - **PAS active (pump) detection limit 0.1 mg/m3/8 hr**
  - PAS passive (badge) detection limit 1 mg/m3/8 hr

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Example n-Hexane

Testing Compliance with Occupational Exposure Limits for Airborne Substances, Sept. 2011
BW_Stat v1.0

	Manual	
1.	Select your language:	English
2.	Enter the name of the substance:	
3.	Enter the units of measurement:	
4.	Enter the occupational exposure limit (OEL):	
5.	Enter the lower limit of quantification (LoQ=accuracy). Typically three times the LoD. Also to be read out from the lognormal probability plot:	
6.	Optional input of the analytical lower detection limit (LoD=accuracy):	
7.	Enter in the tab "Data" the measured concentration levels, taking following into account:	

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Worked example

1. 3 measurements
   - Data entrance (copy/paste)
   - Phase 0: Screening test
   - Phase 1: Group compliance test
2. Additional 6 measurements
   - Phase 1: Group compliance test
   - Phase 2: ANOVA/B&W individual differences test
   - Phase 3: Individual compliance test
   - LOQ Handling

Example n-Hexane

n-hexane		WN1	WN2	WN3
mg/m³	meting 1	10.00		
72.00	meting 2		2.50	
0.04	meting 3			0.20
	meting 4	5.00	1.00	
	meting 5		0.20	1.00
	meting 6	25.00		0.10

Start & Manual | Data | Report | **Examples**

Copy red box from examples : Ctrl-C

Paste option Values : right click mouse

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Nederlandse Vereniging voor Arbeidshygiëne

Example n-Hexane

Copy paste example data

Report: Screening test

Testing Compliance with Occupational Exposure Limits for Airborne Substances, Sept. 2011
BW_Stat v1.0

Invoer			
Eenheid	mg/m3	Stofnaam	n-Hexane
Beroepsmatige blootstellingslimiet (OEL)	72.00	totaal aantal werknemers	3
10% Beroepsmatige blootstellingslimiet (10%OEL)	7.20	totaal aantal meetdagen	3
Onderste kwantificatielimiet (LoQ)	0.10	totaal aantal metingen	3
Resultaten			
Tellingen			
Aantal monsters <10%OEL	2	Aantal monsters <LoQ	0
Aantal monsters =>10%OEL en <=100%OEL	1		
Aantal monsters >100%OEL	0		
Beoordeling blootstelling			

Fase 0: Screening test (Sectie 3.3)	
Is er tenminste één monster =>0,1 OEL?	Ja, voer bijkomende metingen uit tot de steekproefgrootte gelijk is aan 9 (sectie 3.4) of zie resultaten fase 1
Is er tenminste één monster >1,0 OEL?	Neen, alle monsters zijn kleiner dan de grenswaarde

Report: Group compliance test

Testing Compliance with Occupational Exposure Limits for Airborne Substances, Sept. 2011
BW_Stat v1.0

Invoer

Eenheid	mg/m3	Stofnaam	n-Hexane
Beroepsmatige blootstellingslimiet (OEL)	72.00	totaal aantal werknemers	3
10% Beroepsmatige blootstellingslimiet (10%OEL)	7.20	totaal aantal meetdagen	3
Onderste kwantificatielimiet (LoQ)	0.10	totaal aantal metingen	3

Resultaten

Tellingen

Aantal monsters <10%OEL	2	Aantal monsters <LoQ	0
Aantal monsters =>10%OEL en <=100%OEL	1		
Aantal monsters >100%OEL	0		

Beoordeling blootstelling

Fase 0: Screening test (Sectie 3.3)

Is er tenminste één monster =>0,1 OEL?	Ja, voer bijkomende metingen uit tot de steekproefgrootte gelijk is aan 9 (sectie 3.4) of zie resultaten fase 1
Is er tenminste één monster >1,0 OEL?	Neen, alle monsters zijn kleiner dan de grenswaarde

Fase 1: Groep compliance test (Sectie 3.4)

UTL95%,70%	449.57	>	OEL 72 mg/m3
Voldoet de groep aan de OEL?	Voer bijkomende metingen uit tot de steekproefgrootte gelijk is aan 9 (section 3.4)		

Examples: n-Hexane

n-hexane			WN1	WN2	WN3
mg/m³		meting 1	10.00		
72.00		meting 2		2.50	
0.04		meting 3			0.20
		meting 4	5.00	1.00	
		meting 5		0.20	1.00
		meting 6	25.00		0.10

Start & Manual | Data | Report | **Examples**

Add black box from Examples : Ctrl-C

Paste option Values : right click mouse

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Example n-Hexane

	B	C	D	E
	72	worker1	worker2	worker3
		WN1	WN2	WN3
	meting 1	10.00		
	meting 2		2.50	
	meting 3			0.20
	meting 4	5.00	1.00	
	meting 5		0.20	1.00
	meting 6	25.00		0.10

Start & Manual | Data | Report | Examples

Paste option Values : right click mouse

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Stage 2: Individual differences important?

Beoordeling blootstelling

Fase 0: Screening test (Sectie 3.3)			
Is er tenminste één monster =>0,1 OEL?	Ja, zie fase 1		
Is er tenminste één monster >1,0 OEL?	Neen, alle monsters zijn kleiner dan de grenswaarde		

Fase 1: Groep compliance test (Sectie 3.4)			
UTL95%,70%	63.20	<	OEL 72 mg/m3
Voldoet de groep aan de OEL?	Ja, de groep voldoet aan de OEL. Test nu of de verschillen tussen de werknemers belangrijk zijn (Sectie 3.5). Zie fase 2.		

Fase 2: Pas ANOVA toe en indien nodig Fase 3 (sectie 3.5)			
P(ANOVA)	0.02	<	p criterium 0,05
P(ANOVA)	Belangrijke verschillen tussen de werknemers. Test de individuele compliance (Sectie 3.6)		
P(B&W)	72.12%	>	ad-hoc criterium 20%
P(B&W)	Belangrijke verschillen tussen de werknemers. Test de individuele compliance (Sectie 3.6)		

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Nederlandse Vereniging voor Arbeidshygiëne

Stage 3: Individual compliance test

Fase 2: Pas ANOVA toe en indien nodig Fase 3 (sectie 3.5)			
P(ANOVA)	0.02	<	p criterium 0,05
P(ANOVA)	Belangrijke verschillen tussen de werknemers. Test de individuele compliance (Sectie 3.6)		
P(B&W)	72.12%	>	ad-hoc criterium 20%
P(B&W)	Belangrijke verschillen tussen de werknemers. Test de individuele compliance (Sectie 3.6)		

Fase 3: Individuele test (Sectie 3.6)			
Kans dat een individuele werknemer een blootstellings 95%-iel heeft >OEL	11.12%	<	ad hoc criterium 20%
Is er >=20% kans dat een individuele werknemer een blootstellings 95%-iel heeft >OEL?	Neen. Ga over op routine monitoring (herbeoordeling) (Sectie 3.8)		

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Nederlandse Vereniging voor Arbeidshygiëne

3.7 Treatment of values < LoQ

“It is not recommended simply to substitute LoQ/2 or LoQ/√2 for each value < LoQ”

There are ML, regression & Shapiro & Wilks methods.

If no better method is available:

- (1) substitute all <LoQ values by 0.25xLoQ;
- (2) substitute them all by the LoQ;
- (3) substitute half of them by 0.25xLoQ and half by LoQ.

Hear Tom Geens Further developments

“If a method leads to non-compliance, then it is non-compliance”

How to handle undetectables

Fundamental documents:

- Schneider H. Truncated and censored samples from Normal populations. Statistics: textbooks and monographs. Vol 70 (1986).
- Leidel & Busch NIOSH 173 (1977)
- Gupta A.K. Estimation of the mean and the standard deviation of a Normal population from a censored sample. Biometrika 39 (1952) 260-273.

- Fisher R.A. The truncated Normal Distribution. British Assoc. Adv. Sci. Math. Tables I, 1931 pp XXXIII

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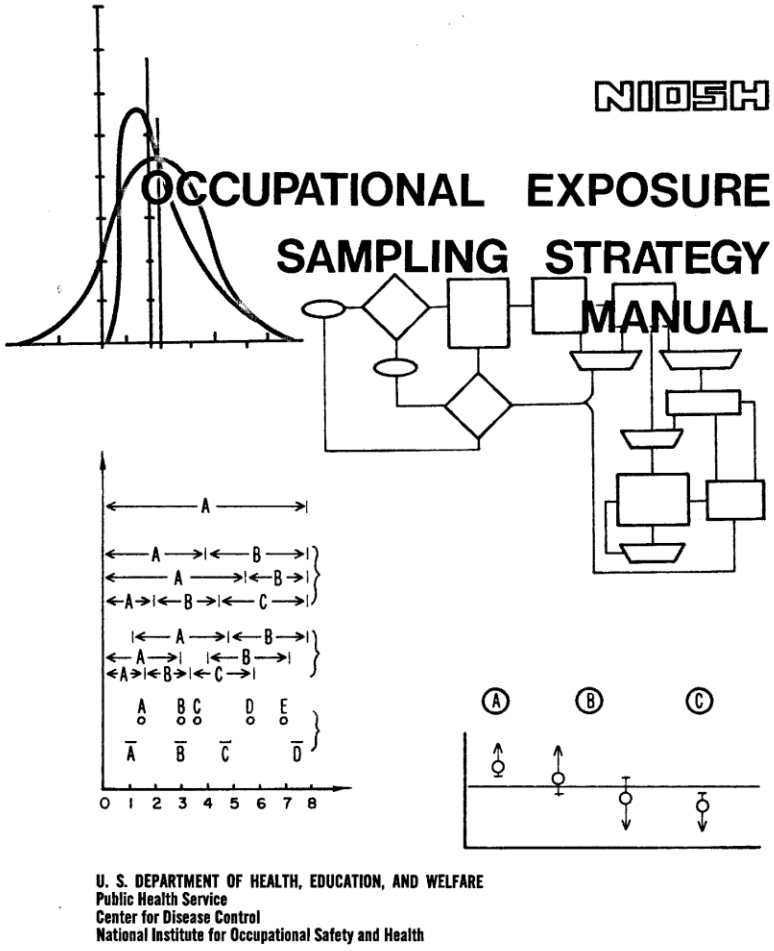
How to handle undetectables

NIOSH 1977: truncated exposure distributions



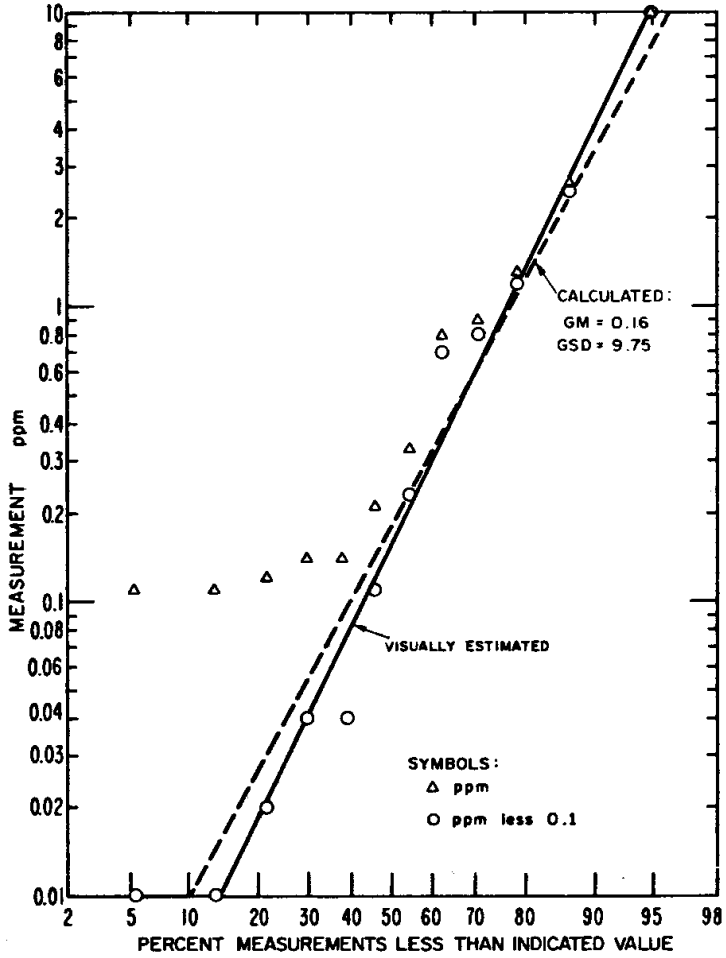


Figure I-4. Hydrogen fluoride measurement distribution.

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Undetectables (n-Hexane example)

Workplace Measurement Method Summaries

2nd IOELV List : HSL/2002/23

- PAS active (pump) detection limit 0.1 mg/m^3/8 hr
- **PAS passive (badge) detection limit 1 mg/m^3/8 hr**
  - Valid method LoQ< 10% of OEL 72 mg/m^3/8 hr

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Nederlandse Vereniging voor Arbeidshygiëne

Higher LoQ->undetectables

B	C	D	E
72	worker1	worker2	worker3
	WN1	WN2	WN3
meting 1	10.00		
meting 2		2.50	
meting 3			0.20
meting 4	5.00	1.00	
meting 5		0.20	1.00
meting 6	25.00		0.10

Start & Manual | Data | Report | Examples

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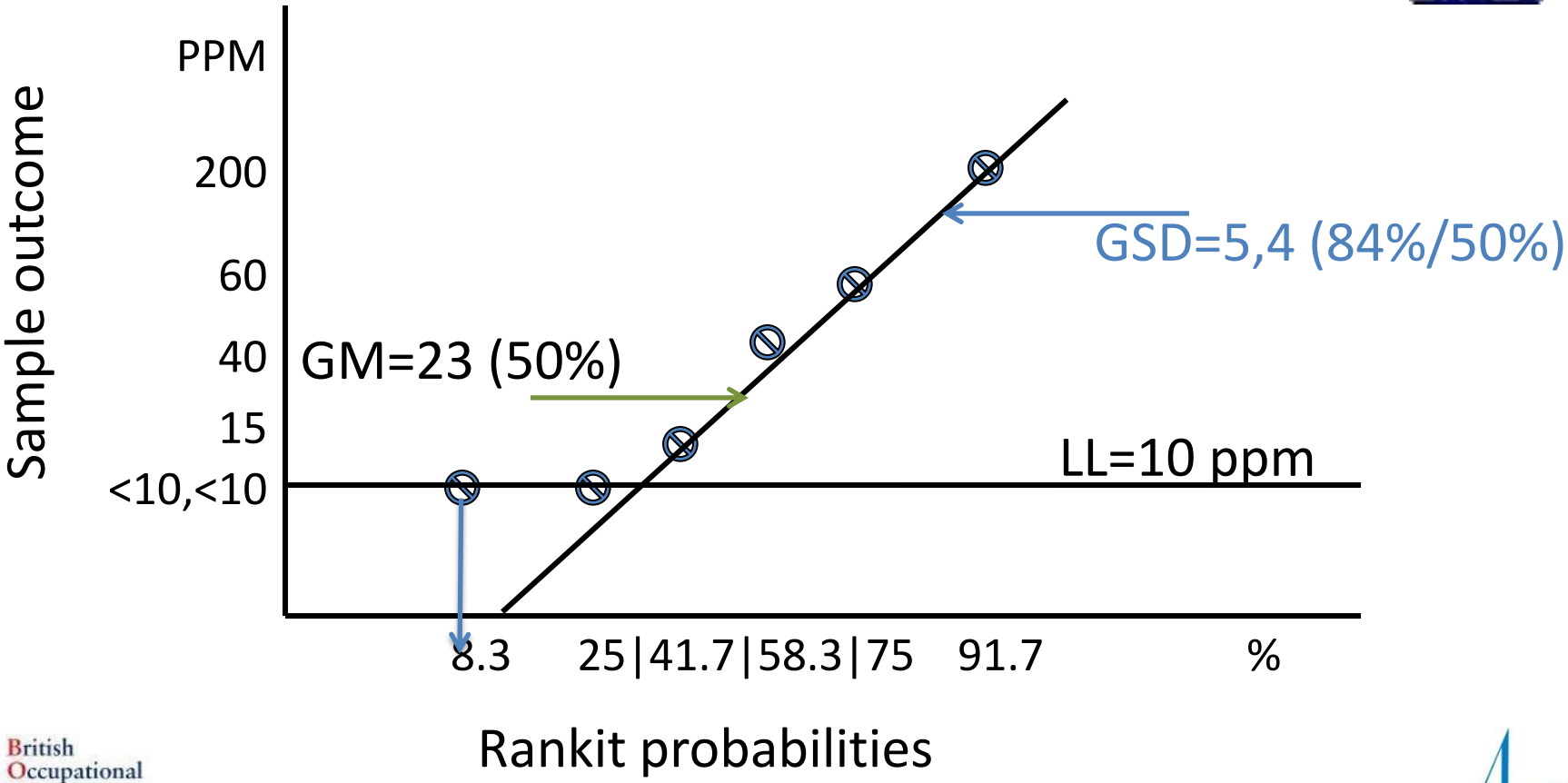
How to handle undetectables

Lognormal propability plot of exposure distribution with undetectables



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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

Contents

- Introduction (Trevor at NVvA /John at BOHS)
- Features (Tom)
- Exercise (Theo)
- **Future (Tom)**
- Contact information

British Occupational Hygiene Society
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Nederlandse Vereniging voor Arbeidshygiëne

Future developments (1)

- Handling <LOQ according to the Guidance

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BW_Stat v1.0

Input			
Unit	mg/m³	Substance name	Katoenstof
Occupational Exposure Limit (OEL)	1,70	total number of workers	3
10% Occupational Exposure Limit (10%OEL)	0,17	total number of measurement days	4
Lower Limit Of Quantification (LoQ)	0,17	total number of measurements	10
Results			
Substitute the values <LOQ:	**0. Use original input measurements**		
Countings			
Number of samples <10%OEL			
Number of samples =>10%OEL and <=100%OEL			
Number of samples >100%OEL			

0. Use original input measurements
1. Substitute all values <LoQ by 0,25*LoQ
2. Substitute all values <LoQ by 1,00*LoQ
3. Substitute half of the values <LoQ by 0,25*LoQ, the other

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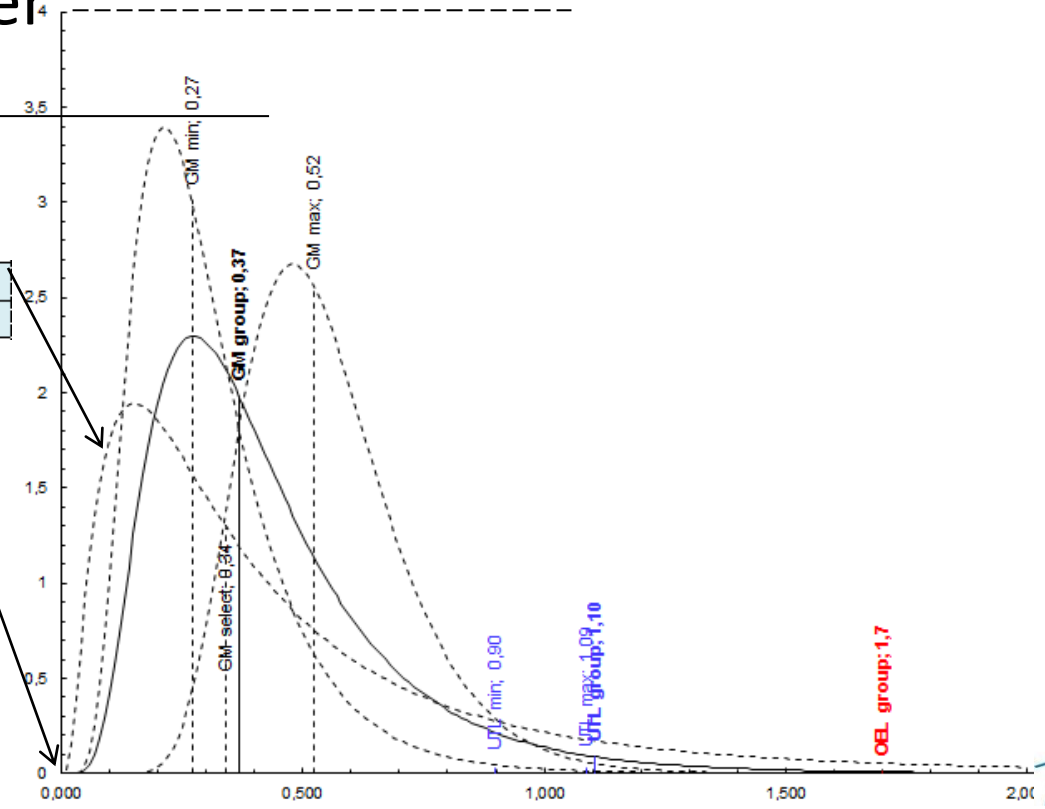
Nederlandse Vereniging voor Arbeidshygiëne

Future developments (2)

- Ideal lognormal distributions for
  - worker with lowest/highest GM
  - selected worker
  - group

Select a worker	Chloe
Enter maximal X-axis value	2



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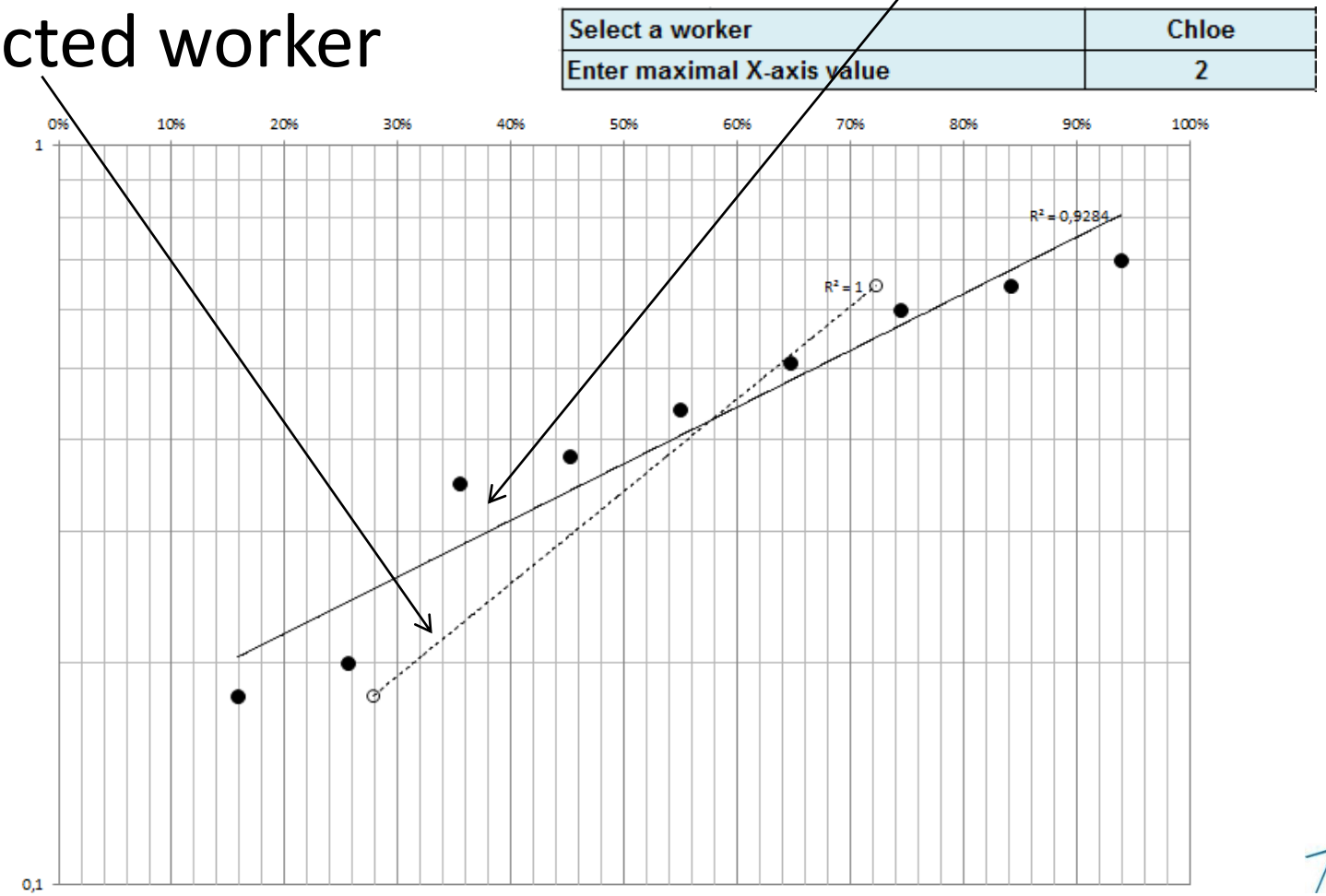
Future developments (2)

Future developments

Individual distributions

Future developments (3)

- Lognormal probability plot for group and selected worker



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Nederlandse Vereniging voor Arbeidshygiëne

Future developments (4)

- Group and individual statistics

Testing Compliance with Occupational Exposure Limits for Airborne Substances, Sept. 2011
BW_Stat v1.0

Individual statistics

	AM	AStdev	GM	GStdev	Shapiro-Wilk	Shapiro-WilkCrit	U	UCrit95%,70%	UTL95%,70%	GMGraph	GStdevGraph rico	Ugraph rico	UCritGraph95%,70%	UTLGraph95%,70%		Lognormal	Compliant95%,70%	CompliantGraph95%,70%
Group	0,42	0,20	0,37	1,73	0,90	0,84	2,80	2,01	1,10	0,37	1,76	2,68	2,01	1,16		1	1	1
Greg (lowest GM)	0,30	0,14	0,27	1,63	0,89	0,75	3,75	2,45	0,90	0,26	1,68	3,60	2,45	0,94		1	1	1
Joe (highest GM)	0,54	0,15	0,52	1,35	0,95	0,75	3,96	2,45	1,09	0,52	0,95	-24,39	2,45	0,46		1	1	1
Individuals																		
Greg	0,30	0,14	0,27	1,63	0,89	0,75	3,75	2,45	0,90	0,26	1,68	3,60	2,45	0,94		1	1	1
Joe	0,54	0,15	0,52	1,35	0,95	0,75	3,96	2,45	1,09	0,52	0,95	-24,39	2,45	0,46		1	1	1
Chloe	0,41	0,33	0,34	2,47	0,98		1,78	4,22	15,40	0,34	2,88	1,52	4,22	29,30		1	0	0

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Nederlandse Vereniging voor Arbeidshygiëne

Future developments (4)

- Group and individual statistics

Testing Compliance with Occupational Exposure Limits for Airborne Substances, Sept. 2011
BW_Stat v1.0

Individual statistics

	AM	AStdev	GM	GStdev	Shapiro-Wilk	Shapiro-WilkCrit	U	UCrit95%,70%	UTL95%,70%	GMGraph	GStdevGraph rico	Ugraph rico	UCritGraph95%,70%	UTLGraph95%,70%		Lognormal	Compliant95%,70%	CompliantGraph95%,70%
Group	0,42	0,20	0,37	1,73	0,90	0,84	2,80	2,01	1,10	0,37	1,76	2,68	2,01	1,16		1	1	1
Greg (lowest GM)	0,30	0,14	0,27	1,63	0,89	0,75	3,75	2,45	0,90	0,26	1,68	3,60	2,45	0,94		1	1	1
Joe (highest GM)	0,54	0,15	0,52	1,35	0,95	0,75	3,96	2,45	1,09	0,52	0,95	-24,39	2,45	0,46		1	1	1
Individuals																		
Greg	0,30	0,14	0,27	1,63	0,89	0,75	3,75	2,45	0,90	0,26	1,68	3,60	2,45	0,94		1	1	1
Joe	0,54	0,15	0,52	1,35	0,95	0,75	3,96	2,45	1,09	0,52	0,95	-24,39	2,45	0,46		1	1	1
Chloe	0,41	0,33	0,34	2,47	0,98		1,78	4,22	15,40	0,34	2,88	1,52	4,22	29,30		1	0	0

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Nederlandse Vereniging voor Arbeidshygiëne

Future developments (5)

- Homogenity of variance

Compliance testing			
Stage 0: Screening test (Section 3.3)			
Are any of the samples =>0,1 OEL?	Yes, see next line		
Are any of the samples >1,0 OEL?	Yes, see stage 1 group compliance test		
Stage 1: Group compliance test (Section 3.4)			
UTL95%,70%	4,74	<	OEL 5 mg/m³
Does the group comply with the OEL?	Yes, the group is in compliance with the OEL. Now check if between-worker differences are important (Section 3.5). See stage 2.		
Stage 2: Apply ANOVA and if necessary Stage 3 (Section 3.5)			
P(ANOVA)	1,00	>	p criterium 0,05
P(ANOVA)	No important differences between the workers. Individual compliance test not needed.		
P(B&W)	-20,00%	<	ad-hoc criterium 20%
P(B&W)	No important differences between the workers. Individual compliance test not needed.		
Stage 3: Individual compliance test (Section 3.6)			
Probability that any worker has an exposure 95%-tile >OEL			
Is there >= 20% probability that individual workers' exposure 95%-tile >OEL?			

1,7	worker1	worker2	worker3	worker4	worker5
	worker 1	worker 2	worker 3	worker 4	worker 5
sample 1	1,17	1,37	1,87	3,50	12,28
sample 2	1,08	1,17	1,36	1,84	3,40
sample 3	1,02	1,05	1,10	1,21	1,46
sample 4	0,98	0,95	0,91	0,83	0,68
sample 5	0,93	0,86	0,74	0,54	0,29
sample 6	0,85	0,73	0,53	0,29	0,08

	AM	AStdev	GM	GStdev
Group	1,50	2,17	1,00	2,35
Individuals				
worker 1	1,01	0,11	1,00	1,12
worker 2	1,02	0,23	1,00	1,25
worker 3	1,09	0,48	1,00	1,56
worker 4	1,37	1,18	1,00	2,43
worker 5	3,03	4,69	0,99	5,98

ANOVA test	
F	0,00
Fcrit	2,76
Between worker variance	-0,14
Total variance	0,71

Levene test	
Levene's W	6,73
Levene's Wcrit	2,76
Max/Min variance ratio	253,61
Equal variances?	No

Variance-analysis

Variation	*Sum of squares*	*Degrees of freedom*	*Mean squares*	*F*	*P-value*	*Critical value*
Between Groups	0,000262969	4,00	6,57421E-05	7,74281E-05	0,999999987	2,75871047
Within Groups	21,22682385	25,00	0,849072954			
Total	21,22708682	29,00				

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Nederlandse Vereniging voor Arbeidshygiëne

Contents

- Introduction (Trevor at NVvA /John at BOHS)
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- Exercise (Theo)
- Future (Tom)
- **Contact information**

British Occupational Hygiene Society
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Nederlandse Vereniging voor Arbeidshygiëne

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