

Training EN 689:2018 middagdeel

Verdieping & Aanvullingen

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Training EN 689:2018 middagdeel

Doe je pet als belangenbehartiger van je werk/opdrachtgever af en denk vanmiddag mee als professioneel arbeidshygienist/ beoordelaar van de blootstelling

conform [NVvA beroepscode](#)



Kahoot!

Presentation structure

1. Support

2. Definitions

Increase Efficiency/Reliability

3. Zoom

4. EN689 priors

5. Additional priors

4.1 None

4.2 Representative

4.3 (log)Normal

4.4 LoD

Variability (GSD)

- I. Preliminary test (§5.5.2)
- II. Validation SEG (§5.4)
- III. Sample size (§5.3 & 7)

Bayesian statistical tools

Instruments

Application

Included in the
sheets

- A. Homogeneity SEG
- B. 'typical' GSD
- C. Models & History
- D. Compare

Verdieping & Aanvullingen

1. Maatschappelijk draagvlak
2. NL definities en begrippen

Efficiency/betrouwbaarheid vergroten:

3. Inzoomen op het hoogste risico.
4. EN689 vóóronderstellingen (=Priors)
5. Aanvullende Priors

Verweven in de presentatie:

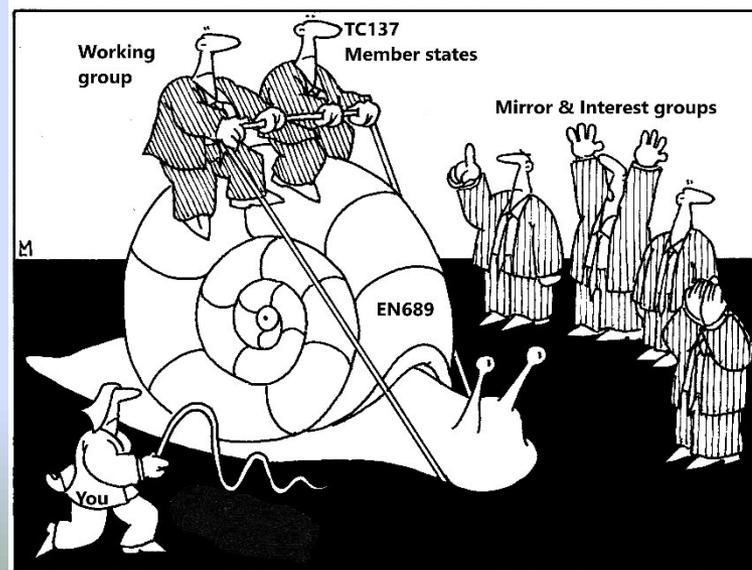
- Geschikte (online) instrumenten
- Bruikbaarheid buiten (EU) Arboregelingen





Verdieping & Aanvullingen

1. Maatschappelijk draagvlak



1. Maatschappelijk draagvlak

Samenstelling

- arbeidshygiënische kwaliteit/belangenverenigingen (o.a. NVvA, BOHS)
- overheid
- industrie (branche) organisaties
- lab consultancy
- instituten (TNO, IFA, INRS) al dan niet gelieerd aan overheid/ sociale verzekeringen

Niet:

- Werknemers
- Universiteiten



Kosten overwegingen hebben meegespeeld bij de preliminary test (n=3-5) en bij de keuze voor het $C_{95\%70\%} \leq OELV$ criterium. Beiden zaten echter ook al in BOSH-Nvva [19 lidstaten van CEN stemden voor, 1 tegen, 13 onthoudingen en 1 nonresponse](#)

Maatschappelijk draagvlak EN 689: “breder is in Europa niet bereikbaar”

Dus: gebruiken deze standaard, maar niet kritiekloos!



Instrumenten

Welke **Freeware** sluit aan op EN689:2018?

1. BWStat V3 online (incl. Preliminary test)
2. HYGINIST

Instrumenten met $C_{95} > 70\%$

IHSTAT (AIHA)

IHDA-S ($N \leq 25$), EXPOSTATS

Lognormal parametric statistics	
Estimated Arithmetic Mean - AM est.	47.700
LCL1,95% - Land's "Exact"	24.700
UCL1,95% - Land's "Exact"	495.000
95th Percentile	181.737
UTL95%,95%	1760
Percent above OEL	13.5%
LCL1,95% %>OEL	2.65
UCL1,95% %>OEL	42.4

[ISZW zelfinspectie werken met gevaarlijke stoffen](#)



Verdieping & Aanvullingen

2. Definities

Similar Exposure group

Group of workers having the same general exposure profile for the chemical agent(s) being studied because of the similarity and frequency of the tasks performed, the materials and processes with which they work, and the similarity of the way they perform the tasks (= SEG)

Een internationaal geaccepteerde definitie:

EN 689:2018 § 3.1.3 & AIHA 1998, 2006, 2015

Beoordelen op groepsniveau: Arbeidshygiënisch principe èn kostenbesparend!



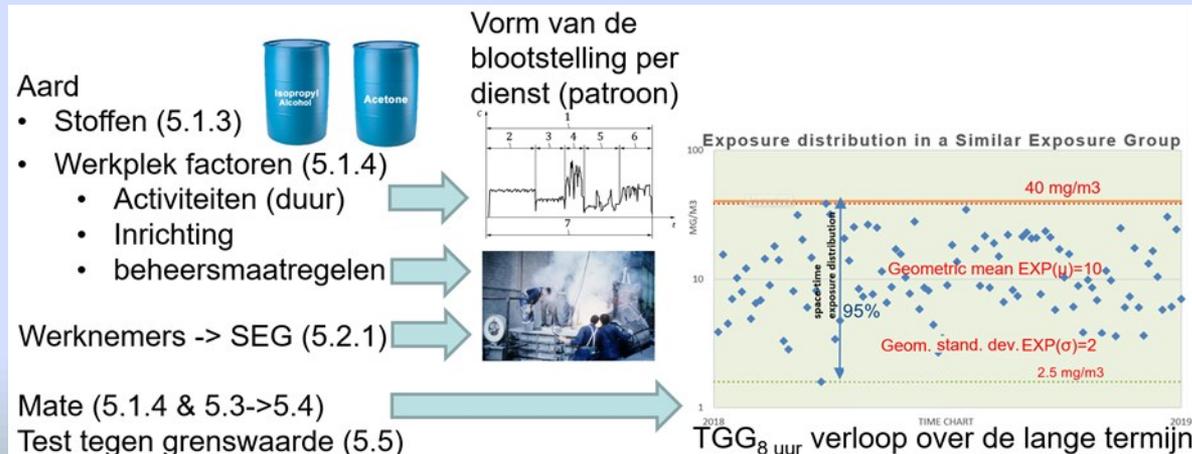
SEG Nederlandse vertaling

Similar Exposure Group (SEG):

Een groep werknemers met een gelijkaardig en gelijkwaardig, lange termijn blootstellingprofiel

EN 689:2018 5.2.1 The SEG shall be constituted using information on the profile of exposure and duration of the tasks performed in the working shifts **throughout the year**

SEG: werknemers met een identiek blootstellingsprofiel





Verdieping & Aanvullingen

1. Maatschappelijk draagvlak
2. NL definities en begrippen

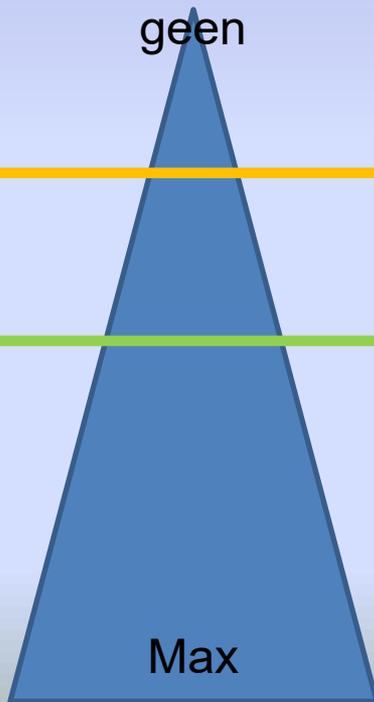
Efficiency/betrouwbaarheid vergroten:

3. Inzoomen op het hoogste risico.
4. EN689 priors
5. Aanvullende priors

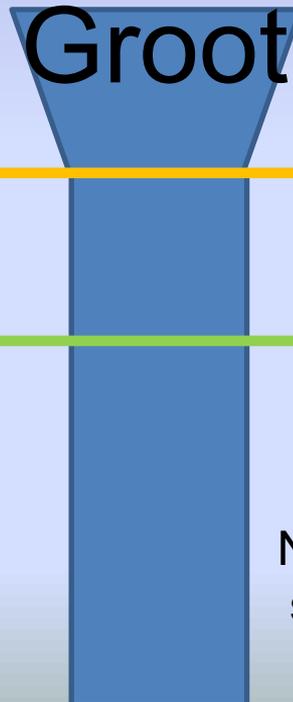


Efficiency/betrouwbaarheid vergroten

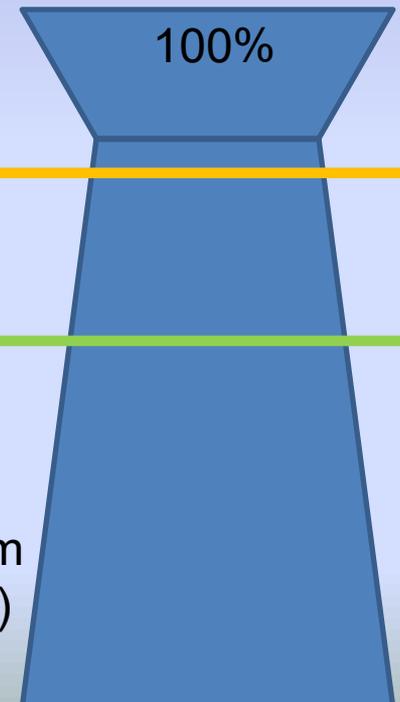
Priors



Inspanning



Betrouwbaarheid



EN689:1995

EN689:2018

NVvA/EU platform
standaard (202#)



Verdieping & Aanvullingen

Efficiency vergroten:

3. Inzoomen

Efficiency/betrouwbaarheid:

3. Inzoomen op het doel.

1. Naleving & handhaving: [ISZW zelfinspectie in 4 stappen](#)
 - I. Gevaarlijke eigenschappen, CMR en toepassingrestricties
 - II. Modellen, meten (EN689), wettelijke grenswaarden
 - III. Maatregelen (arbocatalogie) & Borging
2. gezondrisico en -aansprakelijkheid
 - 1. I.&II. + EN689, [gezondheidskundige grenswaarden uit hiërarchie](#)(ochtendpresentatie)
3. Interventie, validering veilige werkwijzen op bedrijfsniveau, landelijk of Europees(REACH)
 - 2. + BOSH-NVvA(2011), ANOVA



Efficiency:

3. Inzoomen tussen en binnen SEG's.

1. stoffen (§ 5.1.2) rangordenen op gezondheidsgevaar (Hazard banding) & blootstellingsrisico RAS*
2. Blootstelling rangordenen met modellen, buitenlandse databases, eerdere metingen & expert judgement (§5.1.4)
 - Tussen SEG's, binnen een bedrijf/branche
 - (Worst-case) activiteiten binnen één SEG



* Risk Assessment Score

DOHSBase Compare EU 20-01

File Mode Language Help

Compare: file workshop Change mode

Select Compare

TDX: IFA Spaltenmodell DELV: TWA 8 hr in mg/m3

List of substances sorted on Risk Assessment Score (RAS)

Name	CAS-number	Physical state	H/EUH-code(s)	TDX	C_sat	DELV	TDX	RAS
butan-1-ol	71-36-3	Liquid	H226 H302 H335 H336 H315 H318. At least one (a	4	2,6 E+04	61,0000000	1,5	6,0
toluene	108-88-3	Liquid	H225 H361d*** H304 H336 H373** H315. At least c	3	1,4 E+05	192,0000000	1,6	4,8

List of substances with no RAS-value

Name	CAS-number	Physical state	H/EUH-code(s)	C_sat	TDX	DELV
phenol	108-95-2	Solid, v.p. 1 ppb	H314 H331 H311 H301 H373** H314. At least one (a	0 E+00	4	8,0000000

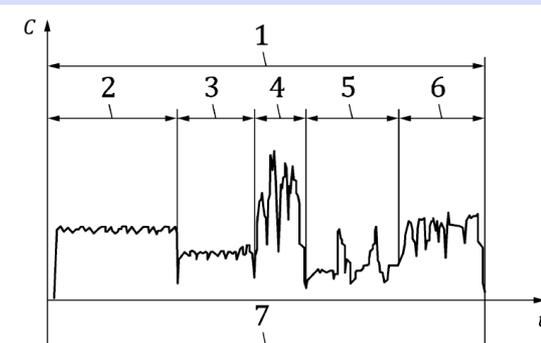
Size database Compare: 98206 Selected: 3 1.590 MB 13-10-2020 07:38:34

Kick-off levels for dust/aerosols
(basis: COSHH Essentials)

Hazard Group	4	3	2*	1
H-statements	H334, H340, H341, H350, H350i	H300, H310, H330, H351, H360 (F/D/FD/Fd/Df), H361 (f/d/fd), H362, H372	H301, H302, H311, H312, H314, H317, H318, H331, H332, H335, H370, H371, H373, EUH071	H303, H304, H305, H313, H315, H316, H319, H320, H333, H336, EUH066, other H-statements n.o.s., REACH Annex IV
mg/m ³ (dusts)	0,0001	0,01	0,1	1

Kick-off levels for gases/vapors
(basis: DGUV IFA Spaltenmodell)

Hazard Group	4	3	2	1
H-statements	H300, H310, H330, H340, H350, H350i, EUH032	H301, H311, H317, H318, H331, H334, H341, H351, H360 (F/D/FD/Fd/Df), H370, H372, EUH029, EUH031, EUH070	H302, H312, H314, H332, H361 (f/d/fd), H362, H371, H373, EUH071	H304, H315, H319, H335, H336, EUH066, other H-statements n.o.s., REACH Annex IV
ppm (gases/vapors)	0,001	0,01	0,1	5





Online tools

hulp bij het effectief en betrouwbaar beoordelen van
blootstelling

[\(Free\) tools "Exposure assessment"](http://www.tsac.nl/) op <http://www.tsac.nl/>
[AIHA IH Apps & Tools](#)

Efficiency

3. Inzoomen: gebruik 'Olifantenpaadje'

- Basis karakterisering 5.1.5
- Beslissen met ≤ 2 metingen



Beslissing basis karakterisering (§ 5.1.5)

Blootstellingschattingen

- Eerdere metingen
- Databases / literatuur
- Berekeningen op basis van relevante kwantitatieve informatie
- Blootstellingsmodellen

Combineren met ≤ 2 metingen

Komen metingen en modellen overeen ?



≤2 metingen basiskarakterisering

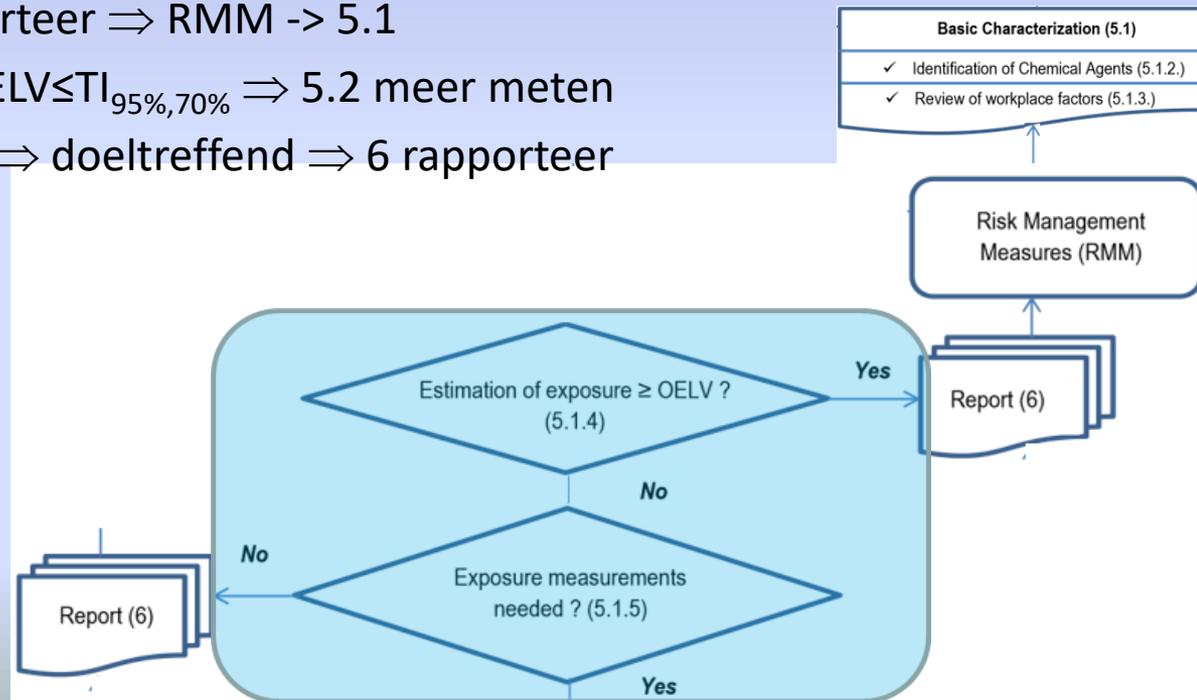
Beoordeling:

Vergelijk GM, GSD met de model/database EXP(μ), EXP(σ) & Student-t

- Indien (significant) afwijkend, herbeoordeel basis karakterisering 5.1.
- Indien niet afwijkend:

1. C_i òf $TI_{95\%,IHStat} > OELV \Rightarrow$ rapporteer \Rightarrow RMM -> 5.1
2. $0.1 < C_i/GW \leq 1$ òf $TI_{95\%,IHStat} < OELV \leq TI_{95\%,70\%} \Rightarrow$ 5.2 meer meten
3. $C_i/GW \leq 0.1$ èn $TI_{95\%,70\%} \leq OELV \Rightarrow$ doeltreffend \Rightarrow 6 rapporteer

Deze aanpak is aan te raden voor $GSD > 4$ of onbekend!



C. Ochtend Voorbeeld 4

- Metingen styreen
- Twee metingen
 - 12,5 mg/m³
 - 17,3 mg/m³ (0.2<OELV≤1)
- GM= 14,7 mg/m³
- GSD=1.26
- GW_{TGG-8hr}: 85 mg/m³

Beoordeel met de **semi-kwantitatieve** ('preliminary') en de statistische C_{95,70%} toets



2 metingen $C_{95,70\%} \leq OELV$

The screenshot shows the HYGINIST version 4.4.2 interface. The 'Compliance' tab is active, displaying the following data:

Descriptive statistics of the current data	
Name	C:\Users\TS_com\zakelijk\projecten\klanten\14_Nvva_689_
Sample size M=	2 samples of 8 hours
Degrees of Freedom df=	1
GM maximum likelihood=	14.7054 mg/m3
GSD=	1.2583

Statistical test: EN689 (2018) clause 5.5.3 & BOHS/NVvA (2011)	
Occupational Exposure Limit Value OELV=	85 mg/m3 \ 8 hours
Confidence that less than 5% of the exposure distribution exceeds OELV	82.9889 %
The 95%-tile upper tolerance limit with 70% confidence =	38.7534 mg/m3
The population fraction < OELV with 70% confidence	99.8434 %

The test shall measure, with 70% confidence, whether less than 5% of the exposures in the SEG exceed the OELV (EN689-2018 clause 5.5.3 _ BOSH/NVvA 2011). Compliance decision (689 Annex F.3) is calculated with the non-central Student distribution using the algorithms of Owen (1968 p464-465).

EN 689(2018) Tuggle(1982)

De 2 metingen voorspellen met 70% betrouwbaarheid dat slechts 0.16% van de concentraties de OELV overschrijden ($\Rightarrow C_{95\%,70\%} = 38.7 \text{ mg/m}^3$)
IHStat Maximum likelihood schatting $C_{95\%} = 21.5 \text{ mg/m}^3$



Analyse met BWStat



BWStat v3 Main page content

Enter substance name:

Styreen

Enter measurement unit:

mg/m³

Enter occupational exposure limit:

85

Data entry

Graphical results

Numerical results

Download

Example data

Paste/Edit data

Upload data

Simulate data

Decimal mark

- Comma
- Point

txtdata

12.5 koen	mon
17.3 koen	tue

Use dataset!

```
Object of class BWStat
2 measurements, 1 worker
OEL: 85
Number of samples below 10% OEL: 0
Number of samples between 10% OEL and OEL: 2
Number of samples above OEL: 0
Lognormal: Yes
Group compliance test:
Geometric mean: 14.70544
Geometric standard deviation: 1.258341
U value: 7.634809
Critical U value (Natrella, 1963): 4.216693
Critical U value (spreadsheet): 4.21677
UTL (Natrella, 1963): 38.75224
UTL (spreadsheet): 38.75292
UTL (Howe, 1969): 38.75224
```

$$U_r < U_T$$

$$TI_{95\%,70\%} = 38.7 \leq OELV = 85 \text{ mg/m}^3$$

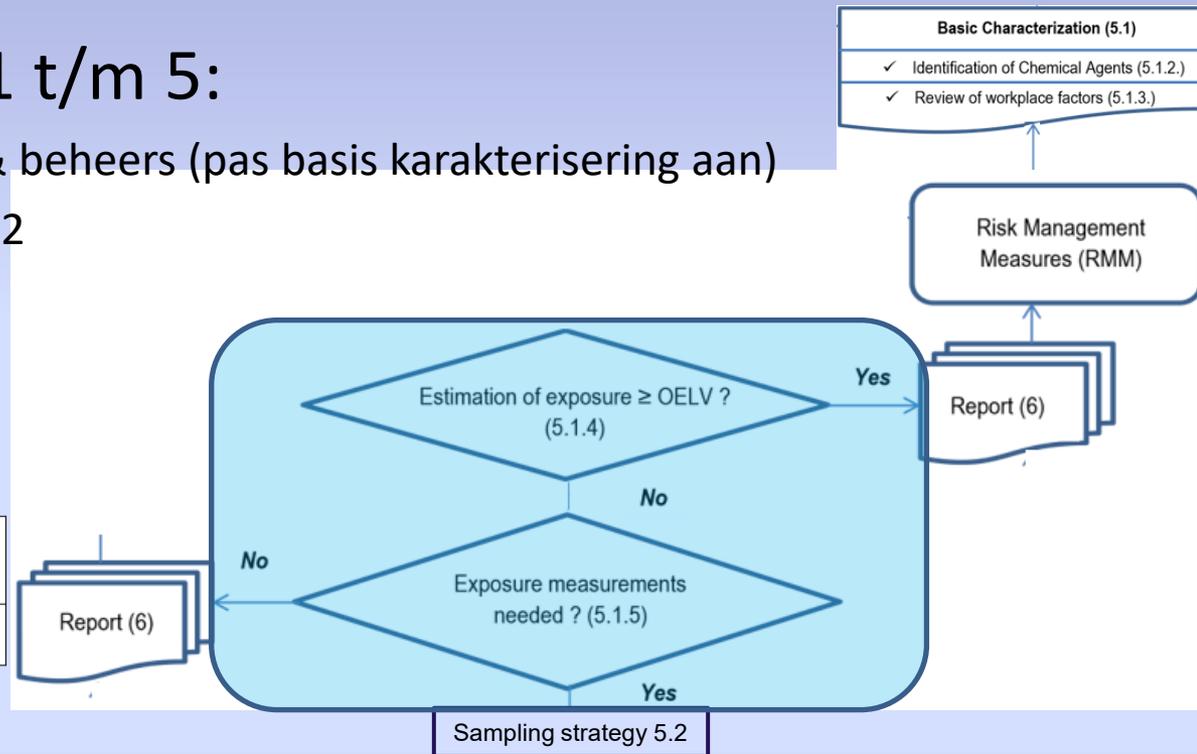
Olifantenpad met 1 -3 metingen

Beoordeling voor i=1 t/m 5:

1. $C_i/GW > 0.1 \Rightarrow$ rapporteer & beheers (pas basis karakterisering aan)
2. $C_i/GW > 0.1 \Rightarrow$ meetplan 5.2.2
3. $C_i/GW \leq 0.1 \Rightarrow$ [zie 4.II.D.](#)

5.1.5 beoordeling vanuit de schatting

Laag	Blootstelling is ruim onder de grenswaarde <ul style="list-style-type: none"> • metingen niet nodig; • rapporteren + advies voor herbeoordeling
Onduidelijk	Onvoldoende informatie om beslissing te nemen <ul style="list-style-type: none"> • Opstellen van meetplan





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Efficiency/betrouwbaarheid vergroten:

3. Inzoomen op het hoogste risico.
4. EN689 vóóronderstelling (=priors)
5. Aanvullende priors



4. EN689 Priors

1. Geen vooronderstellingen
2. Representatief => Meetuitkomsten \Leftrightarrow SEG
3. (Log)normaal=> EN689 extrapoleren 5.5.2/3
4. LoQ's horen bij de verdeling



betrouwbaarheid

4. EN689 Priors toetsen

EN689 priors zijn bewezen maar moeten steeds worden getoetst

2. Meetuitkomsten \Leftrightarrow SEG \Rightarrow EN 5.1 t/m 5.3
3. (Log)normal \Rightarrow Waarschijnlijkheidspapier
4. LoQ's horen bij de verdeling \Rightarrow schatten met 'Waarschijnlijkheidspapier' technieken



4. EN 689 Priors toetsen

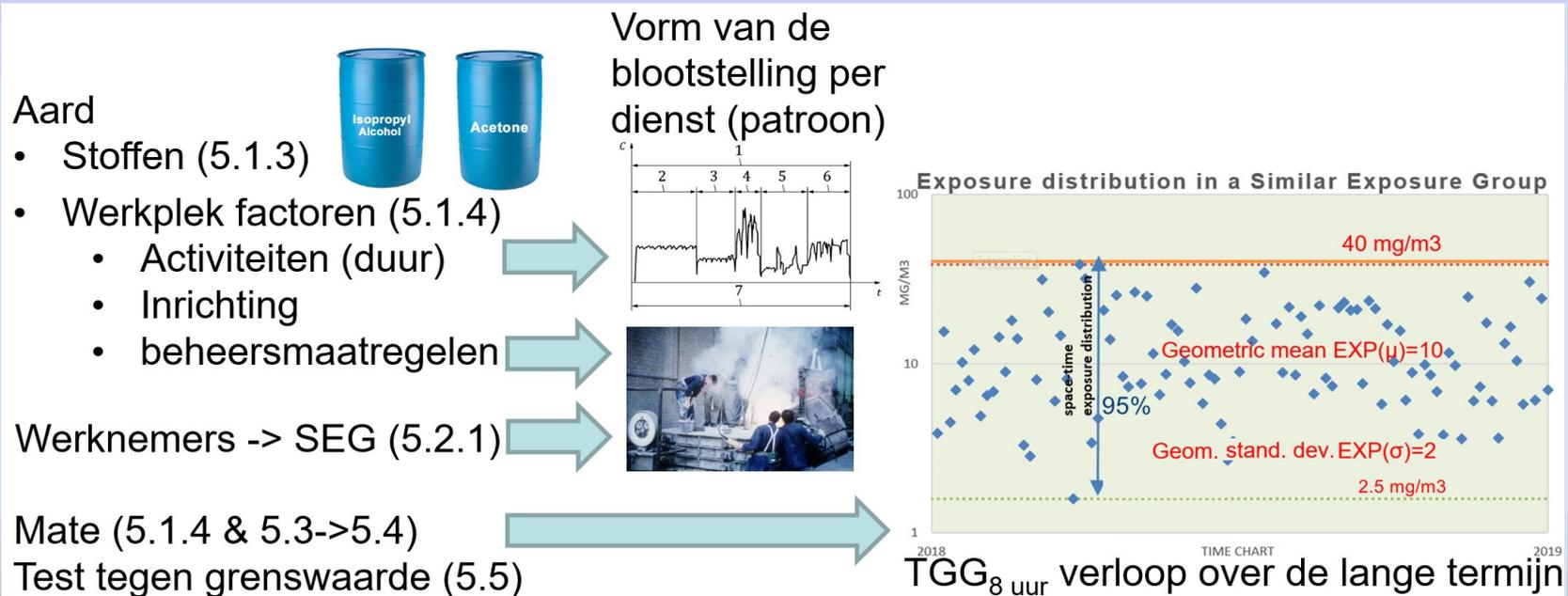
2. Representatief: vertegenwoordigen de verzamelde gegevens (metingen, schattingen) het SEG blootstellingspatroon?

Aard, mate, duur

Vraag (ochtend presentatie)

Wat is de blootstelling van een werknemer (in ruimte en tijd) en is die veilig?

Zijn metingen/modellen representatief voor de **aard, mate en duur** van het onderzochte blootstellingsprofiel



SEG definitie => NL vertaling

Similar Exposure group

Een groep werkenden met een gelijkaardig, **maar niet noodzakelijkerwijs, synchroon** werkpatroon

Voorbeeld 3: 1 of meerdere SEGs?

Verschillende
lijnen, zelfde
SEG?

Taak	Datum	Blootstellingsindex oplosmiddelen (B.I.) (Tier 1)
Afvullen lijn 1	16-10-2019	0,0021
Afvullen lijn 2	16-10-2019	0,0047
Afvullen lijn 3	05-12-2019	0,00016
Afvullen lijn 5	16-10-2019	0,05

Metingen
op 2 dagen

Is dit één SEG?

Ja, indien taak roulatie over de 4 lijnen

Bij vaste (groepen) werkers per lijn ook één SEG indien

1. stoffen identiek
2. werkplek factoren vergelijkbaar èn
3. blootstelling gelijk (BW_Stat/ANOVA)

1 SEG voor N locaties, bedrijven, etc indien aan 1,2,3 wordt voldaan



Voorkeursmeetstrategie bij niet-synchroon werkpatroon?

- A. 9 personen op één dienst
- B. 1 persoon op 9 random diensten door het jaar
- C. 3 personen, 3 random diensten door het jaar
- D. 2 personen, 4 seizoenen & ploegendienst- cyclus, gestratificeerd

meer zwart heeft de voorkeur



betrouwbaarheid vergroten

4. EN689 priors

1. Geen vooronderstellingen
2. Aselecte steekproef => Meetuitkomsten \leftrightarrow SEG
3. (Log)normaal=> EN689 extrapoleren 5.5.2/3
4. LoQ's horen bij de verdeling

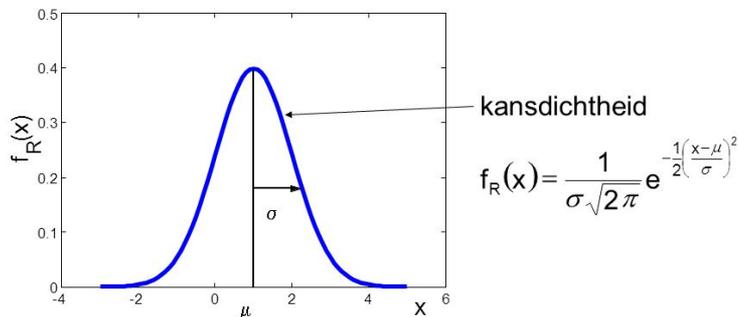


4 EN689 Priors toetsen

3. Beoordelen van de (log)Normale vorm Annex E

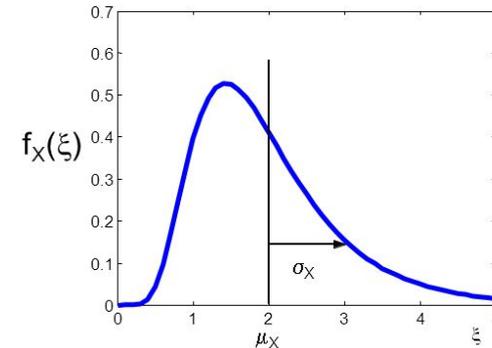
Normaal of lognormaal?

Normale verdeling



μ gemiddelde, indicatie voor ligging
 σ standaarddeviatie, indicatie voor spreiding

Lognormale verdeling



Meetfouten
(monstername & analyse)
 CV_t , bepalen de spreiding

Werkplek factoren
bepalen de spreiding in
veel sterkere maten dan
de meetfouten

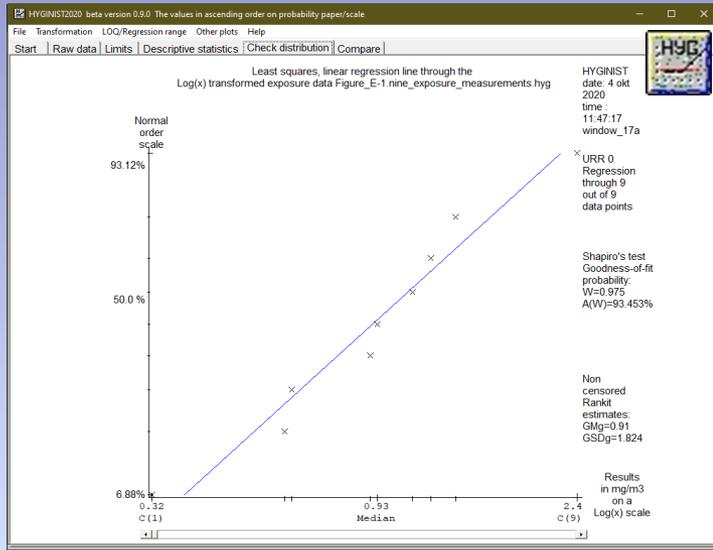
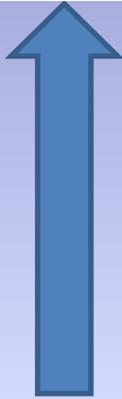
Hoe beoordeel jij de vorm?

- Niet
- Statistisch: $P(\text{Shapiro-Wilks})$ 5%
- Eyeballing: grafisch op (log)normaliteitspapier
- Vergelijk verschillende transformaties

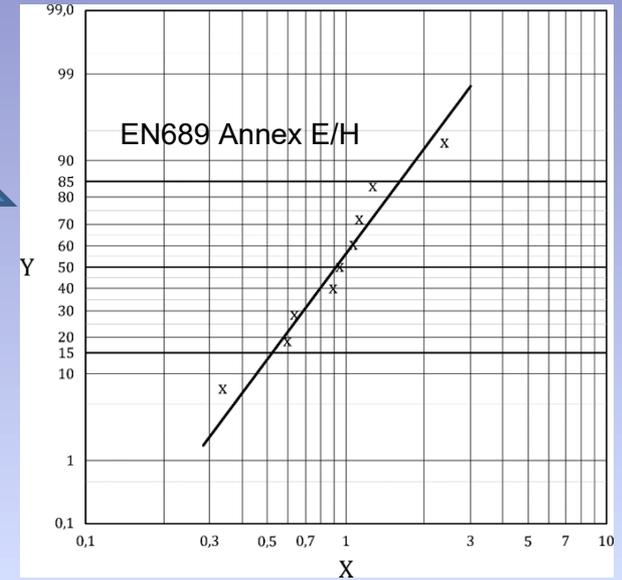


EN 689 Annex E/H assenwissel

Percentage



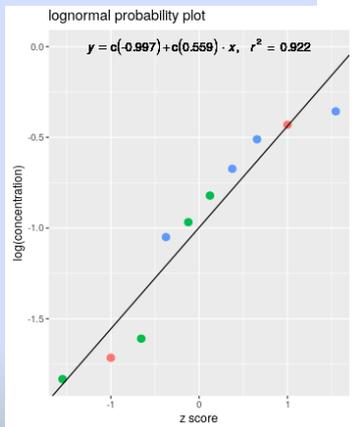
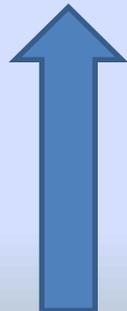
Percentage



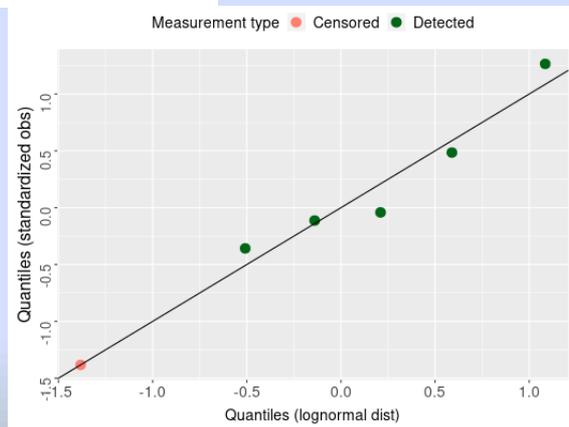
Concentratie

Concentratie

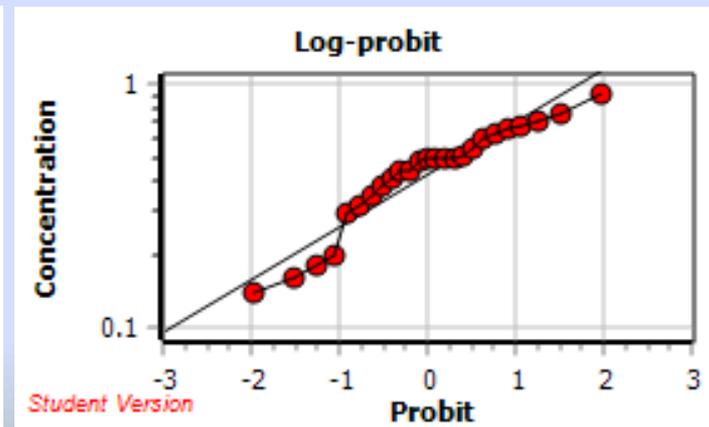
Conc



BWStat Online



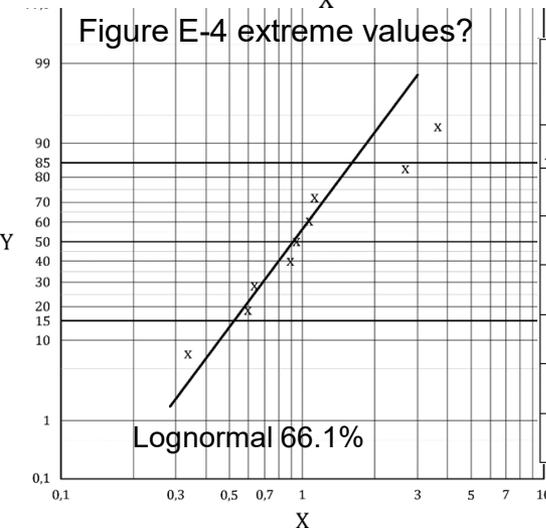
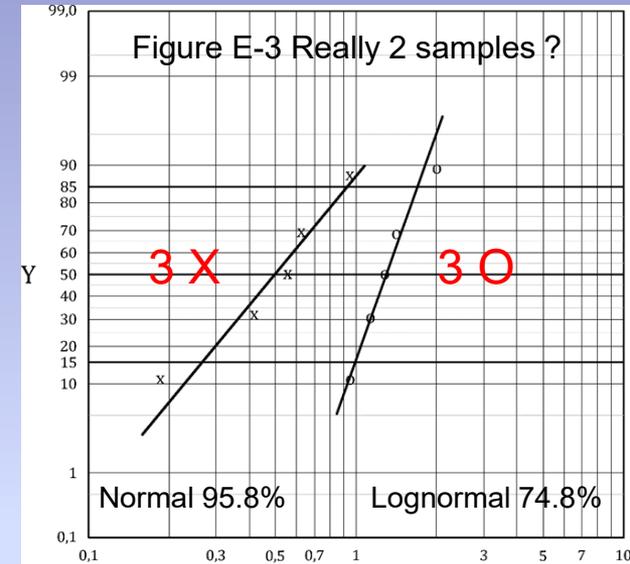
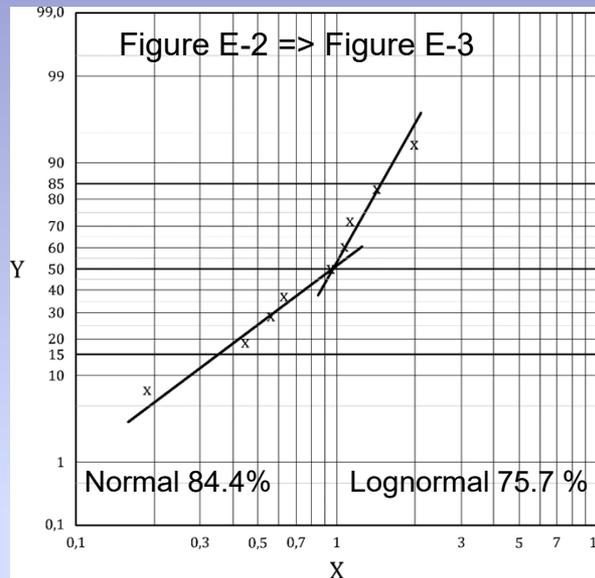
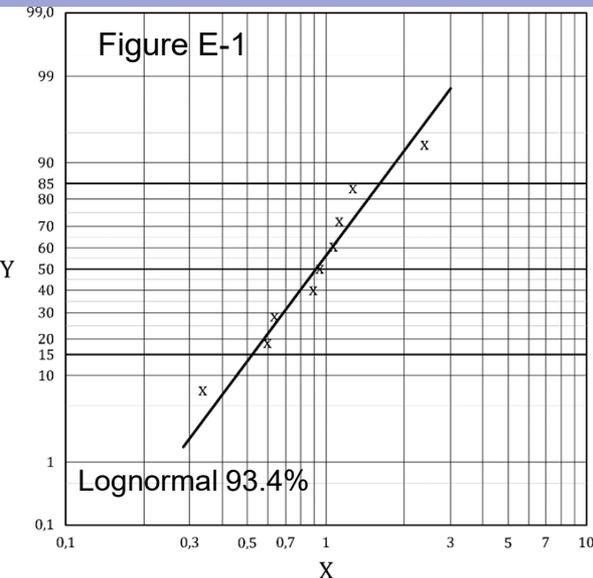
Expostats



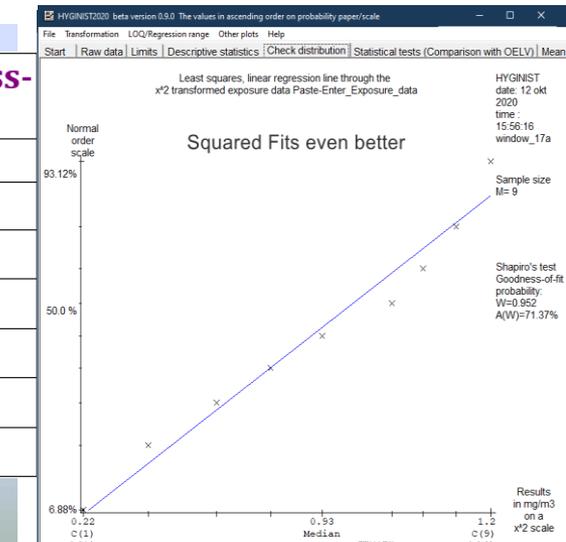
IHDA

Normal or lognormal?

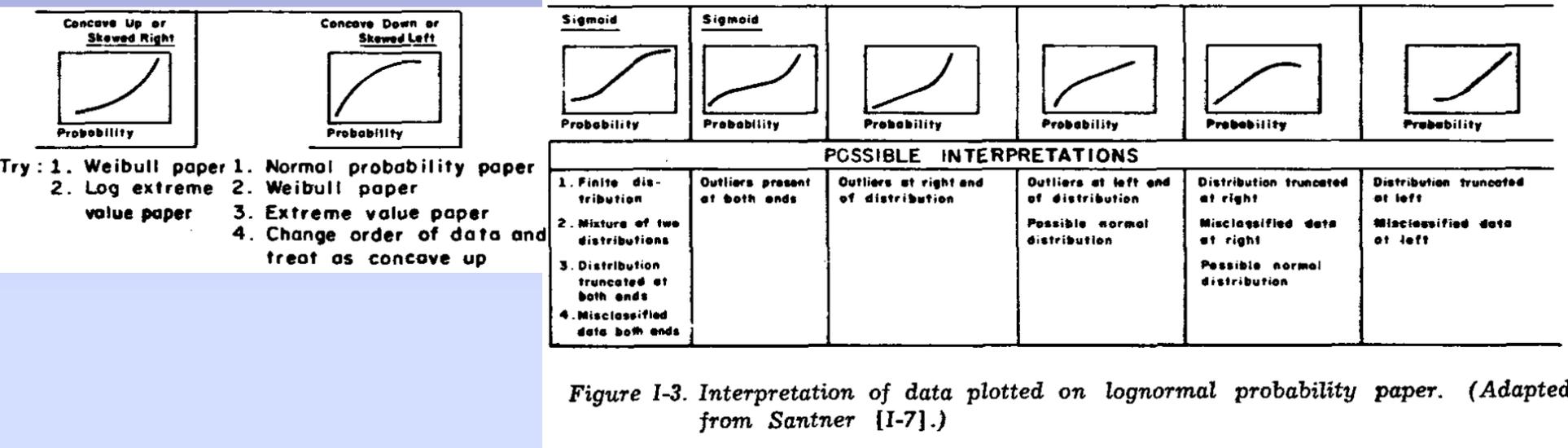
Annex E Dust



Examples in Annex E	Shapiro and Wilk ^[3, 5] goodness-of-fit Probability %		
	<i>lognormal</i>	<i>normal</i>	<i>Square root</i>
Figure E-1	93.4	18.2	78.5
Figure E-2	75.7	84.4	99.5
Figure E-3 set X	67.9	95.8	94.4
Figure E-3 set O	74.8	37.4	55.8
Figure E-4	66.1	1.4	14.8
Figure E-5	1.72	34.3	10.7



Afwijkingen van logNormaliteit



Verklaringen en aanbevelingen

Leidel (1977) pagina 102

<http://www.tsac.nl/publicaties/Leidel & Busch. Niosh.77-173.pdf>

Software

Welke IH **Freeware** beoordeelt het best de vorm?

1. HYGINIST (grafisch, Shapiro&Wilk, meerdere transformaties)
2. [BWStat online](#), [Altrex Chimie](#), IHSTAT, IHDA-S ($N \leq 25$), [EXPOSTATS](#)



Meeneem boodschap

Beoordelen van de vorm:

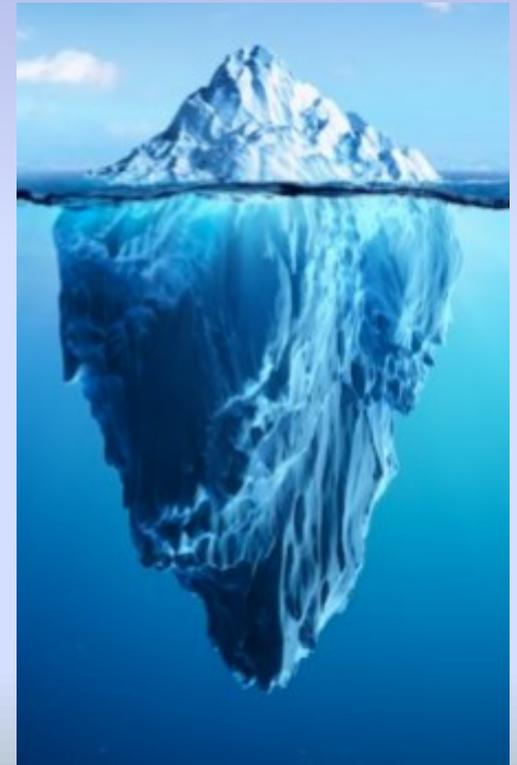
- Eyeballing/op-het-oog alleen is subjectief en daarom beperkt reproduceerbaar tussen collega's
- Geen statistische test 5.5.3 maar terug naar 5.1-5.4 indien
 - goodness-of-fit voor (log)normaal <5%
 - Andere transformaties hogere $P(W)$ waarden hebben
- Statistische test 5.5.3 op een Normaal verdeling indien de random meet fouten (CV_t) de werkplek factoren ook werkelijk camoufleert



Betrouwbaarheid vergroten 4.

4. LoQ's horen er bij!

Kahoot!



Annex H (informative) Exposure below the limit of quantification (LoQ)

Een kenmerk van de teller (massa, analyse, het laboratorium) en noemer (monstername duur en volume, de strategie) van de concentratie

$$\text{LoQ} = .1 * \text{GW} \text{ (EN482)}$$



Substitution method $0.5*LoQ$

Editorial

Ann. Occup. Hyg., Vol. 54, No. 3, pp. 255–256, 2010
© The Author 2010. Published by Oxford University Press
on behalf of the British Occupational Hygiene Society
doi:10.1093/annhva/mer099

Handling results below the level of detection

T. L. OGDEN*

*Chief Editor, Annals of Occupational Hygiene, British Occupational Hygiene Society,
Melbourne Court, Millennium Way, Derby DE24 8LZ, UK*

Received 23 December 2009; in final form 23 December 2009.

Perhaps the most controversial of these is that the substitution method is so flawed compared to other methods that journals should 'reject papers that use

it.'

$$C_{LoQ} = .5 * LoQ$$

Detectie grenzen

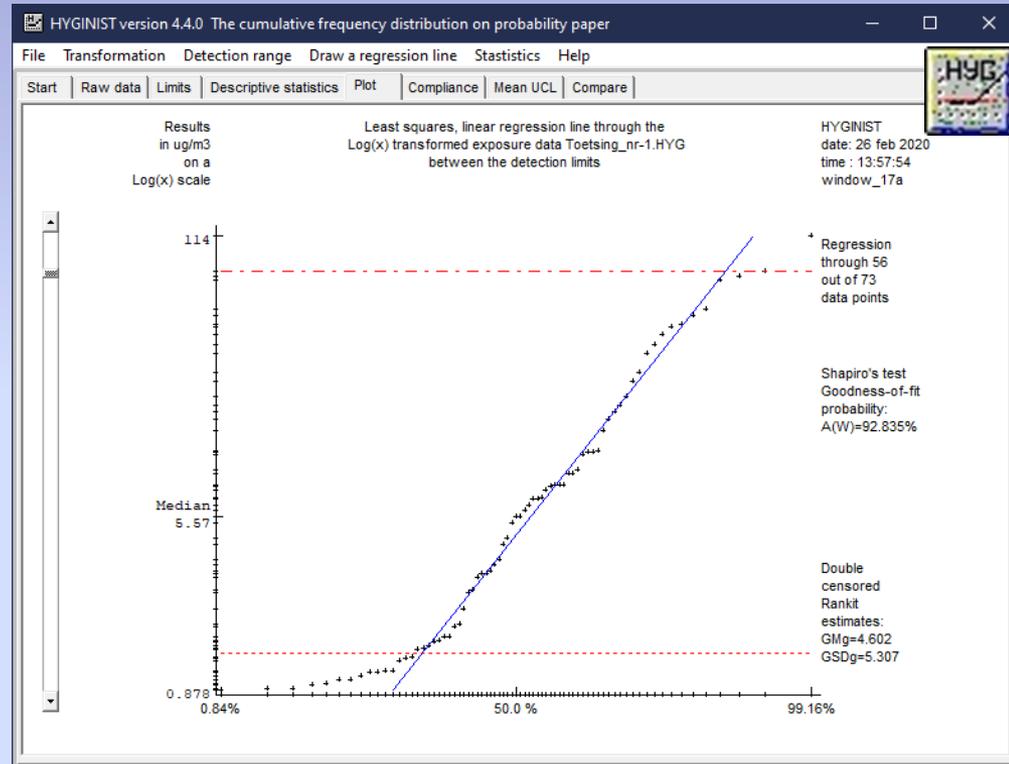
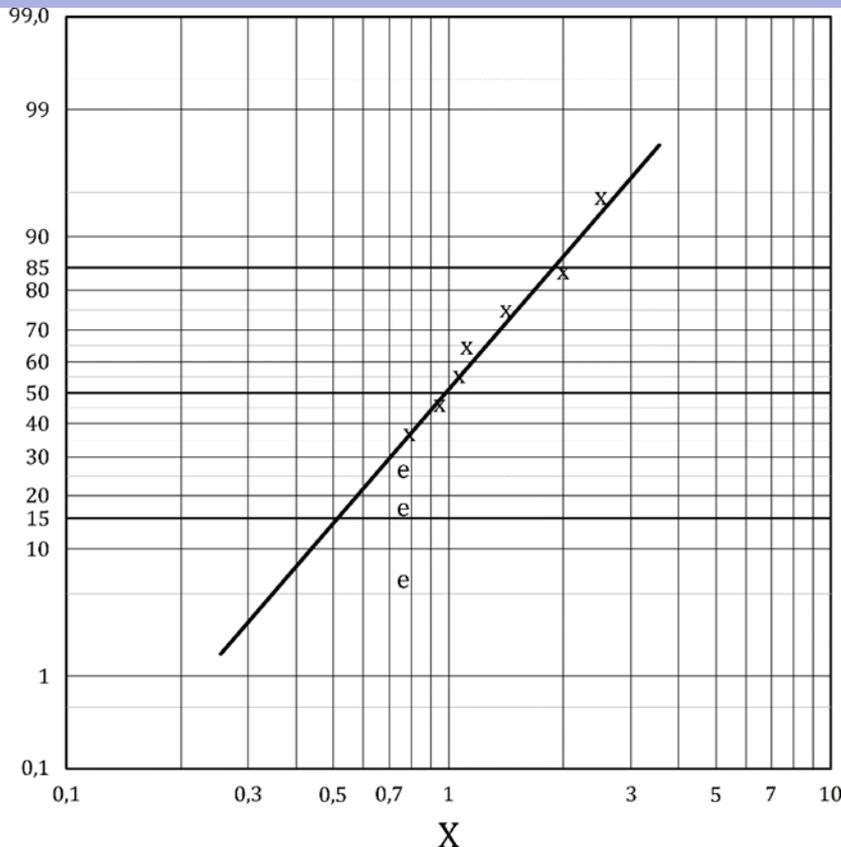
Complexe zaak, voor analytici

- Wordt bepaald door de standaarddeviatie (SD) van meerdere (10) blanco metingen
- $LoQ = 3 * SD \Rightarrow$ 'er is iets'
- $LoQ = 10 * SD \Rightarrow$ 'er is een hoeveelheid'
- LoQ genoemd in EN 689:2018 3.2, Annex E, H
- BOG= BepalingsOnderGrens bij vezelmetingen
- HYGINIST bepaalt observationeel de detectiegrens (analyse + monstername + 'real world')

BOG= BepalingsOnderGrens bij vezelmetingen

- het aantal X dat correspondeert met 5% waarschijnlijkheid bij het tellen van 0 vezels in N velden.
- Deel je X door het aangezogen volume dan heb je de vezel bepalingsondergrens

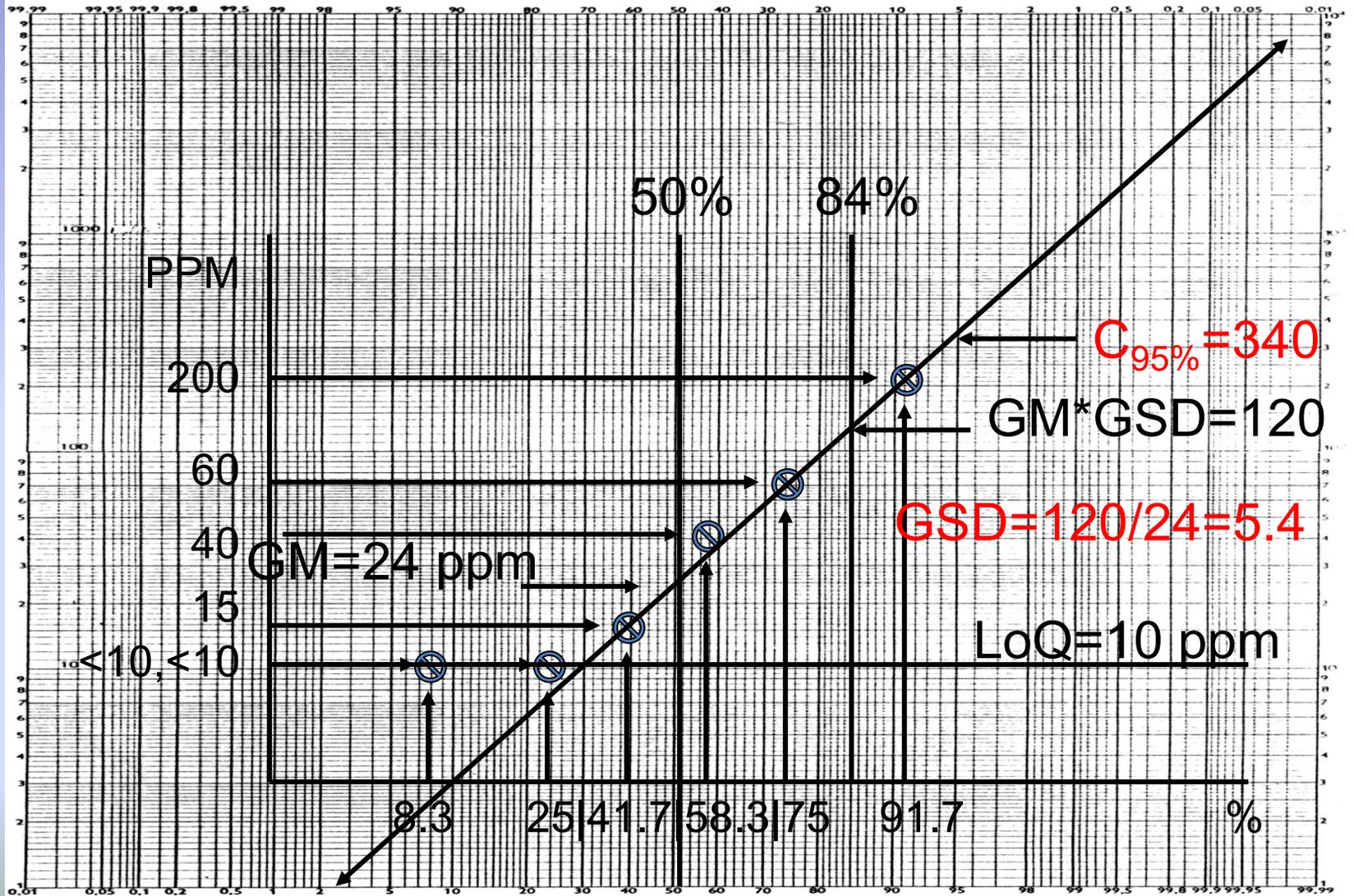
Annex H (informative) Exposure below the limit of quantification (LoQ)



Lab en verdeling LoQ.
meetmethode en stoffeigenschappen LuQ:
schat de verdeling met het deel van de steekproef dat (log)Normaal is

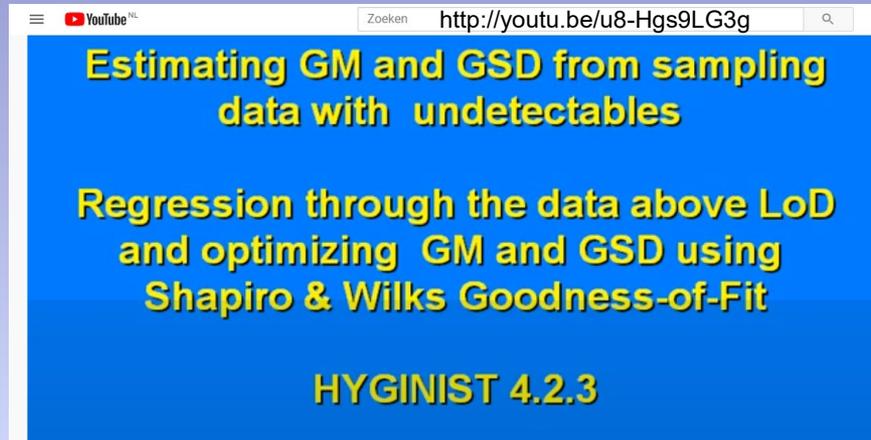


Ranstaapingsmetode voor uitwerktelementen



Observationele detectiegrenzen

[HYGINIST YouTube demo](#)



9

HYGINIST DEMO manual

4. DESCRIPTIVE STATISTICS

4.2. Censored sample

If at least one result lies outside the detection range (window 17bcd), then GM and GSD are derived from the least squares, linear regression line through the data points within the detection range, using the algorithms for the Type I, single and double sided, censored sample (Gupta 1952, Prescott 1970). For J ($j=1, \dots, J$) results within the detectionrange, GSD is calculated using:

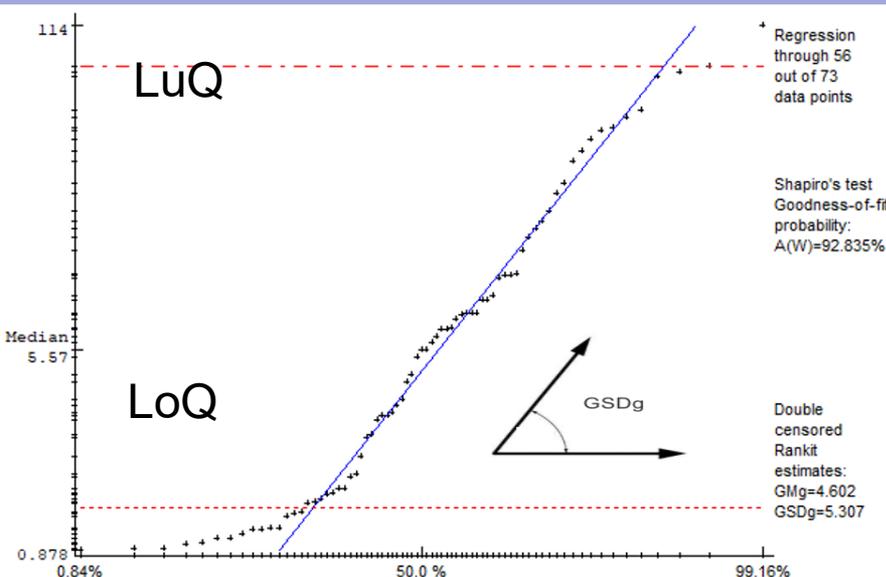
$$GSD^s = \text{EXP}((\sum(R_j x_j) - \sum R_j \sum x_j) / (\sum(R_j)^2 - (\sum R_j)^2 / J))$$

The geometric mean GM^s is estimated by interpolation to the median:

$$GM^s = \text{EXP}\{(\sum x_j) / J - \log(GSD^s) * \sum R_j / J\} \quad (9)$$

©Copyright 1990,1991 Theo Scheffers, 11 september 1991. All rights reserved.

GSD for restricted goodness-of-fit



$$GSD^g = \text{EXP} \left[\frac{\sum_{i=II}^{i=ul} R_i * x_i - \frac{\sum_{i=II}^{i=ul} R_i \sum_{i=II}^{i=ul} x_i}{M'}}{\sum_{i=II}^{i=ul} R_i^2 - \frac{\left(\sum_{i=II}^{i=ul} R_i \right)^2}{M'}} \right]$$

Lognormal GSD regression estimate

R_i : normal order statistic. M' sample size detectables

$j=II$ the first outcome above the LoQ

$j=ul$ the last outcome below the LuQ

<https://www.bsoh.be/?q=nl/bwst>
at

30 Years
BSOH
1989 - 2019

BELGIAN SOCIETY FOR OCCUPATIONAL HYGIENE

Welkom theo.scheffers@tsac.nl | [Logout](#)

Nederlands

BWStat v3

Enter substance name:

Enter measurement unit:

Enter occupational exposure limit:

Choose imputation method:

Analyse dataset!

Data entry Graphical results Numerical results Download

Example data Paste/Edit data Upload data Simulate data

Choose dataset:

Load dataset!

Annex H.3 $.5 * LoQ$



Substitute LoQ values with $0.5 * LoQ$

Enter substance name:

Enter measurement unit:

Enter occupational exposure limit:

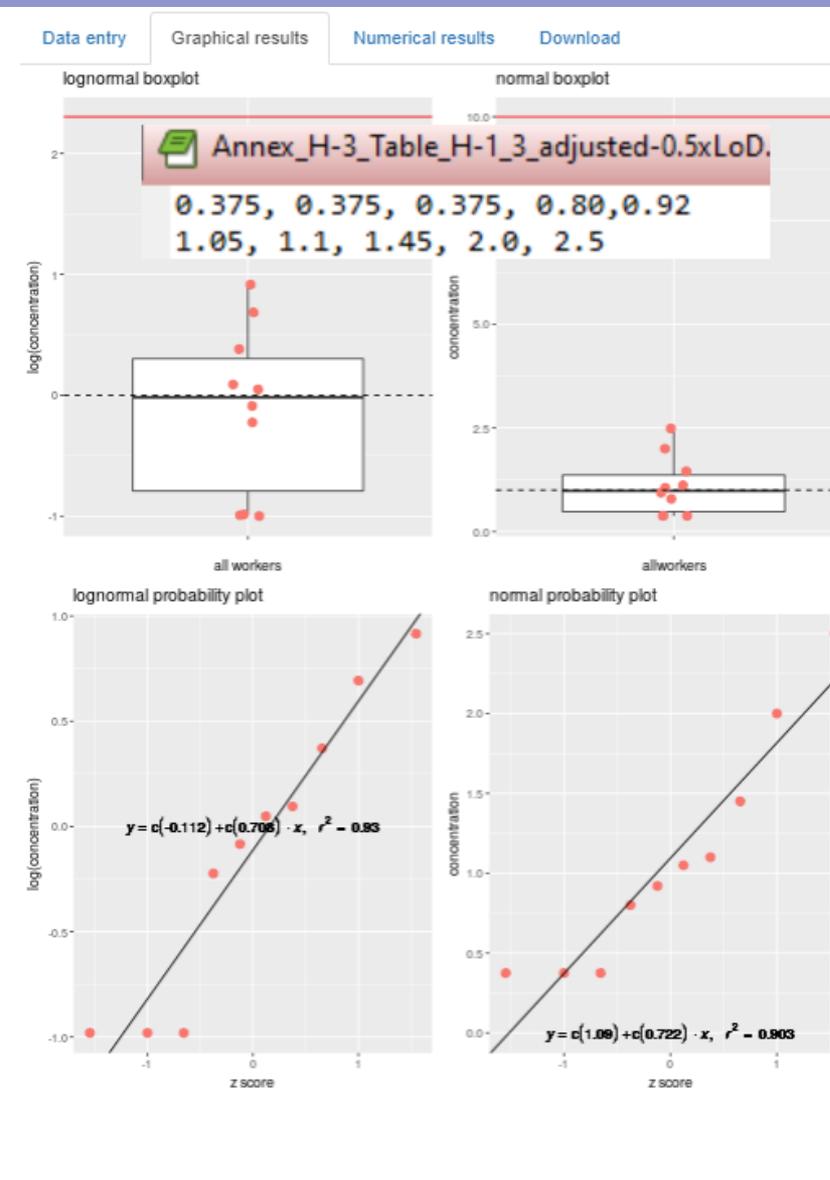
Choose imputation method:

OEL value: 10
 Conclusion screening: More than 5 samples!
 Exceedance fraction: 0%
 Conclusion exceedance: Legal compliance

UTL95,70 value: 3.566
 Conclusion (utl): UTL95,70 < OEL: statistical compliance

Ucrit value: 2.005
 Ucalc value: 3.499
 Uregr value: 3.413
 Conclusion (calc): Ucalc > Ucrit: statistical compliance
 Conclusion (regr): Uregr > Ucrit: statistical compliance

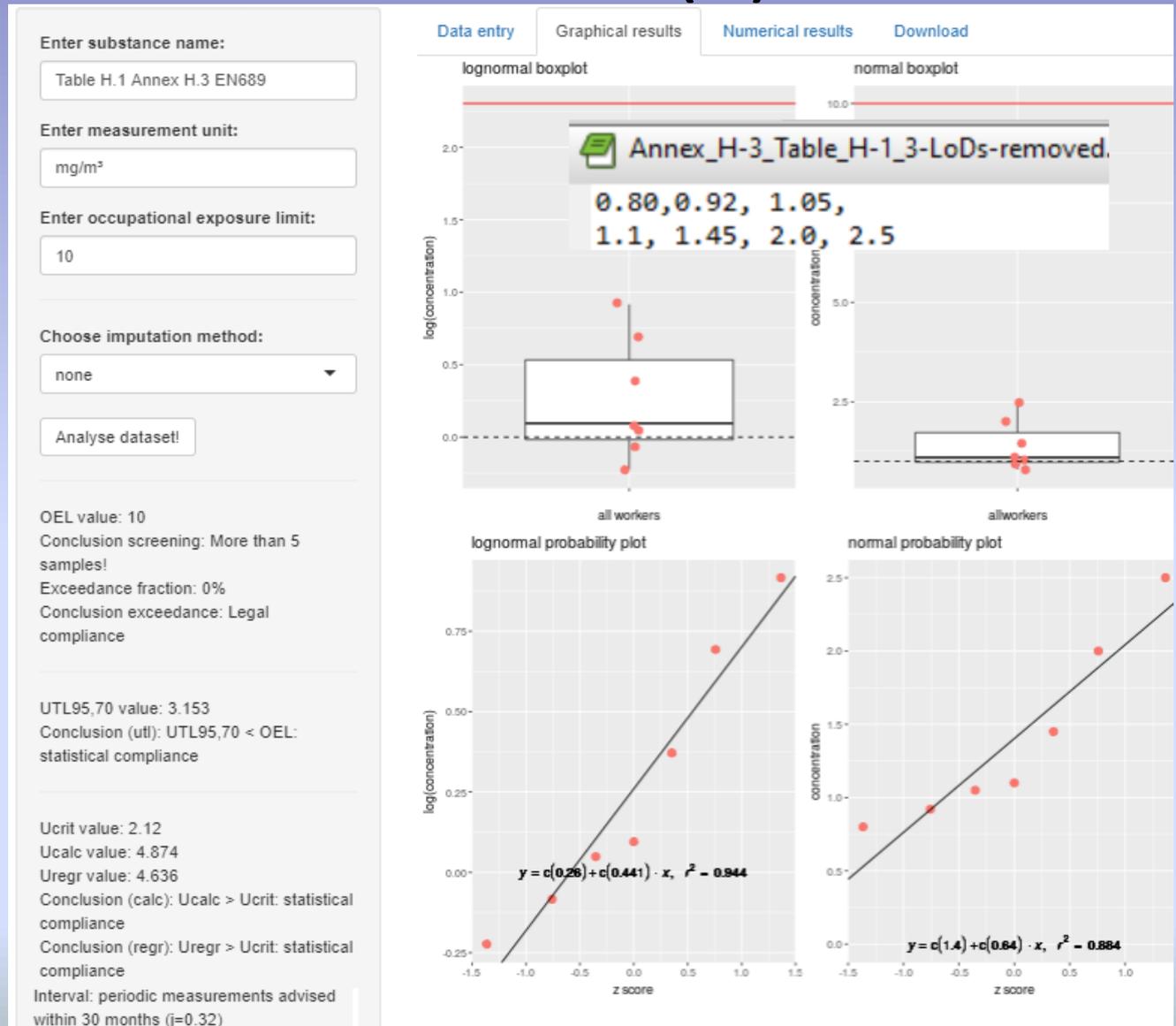
Interval: periodic measurements advised within 30 months (j=0.36)



Annex H.3 (1)



Remove all 3 LoQ values

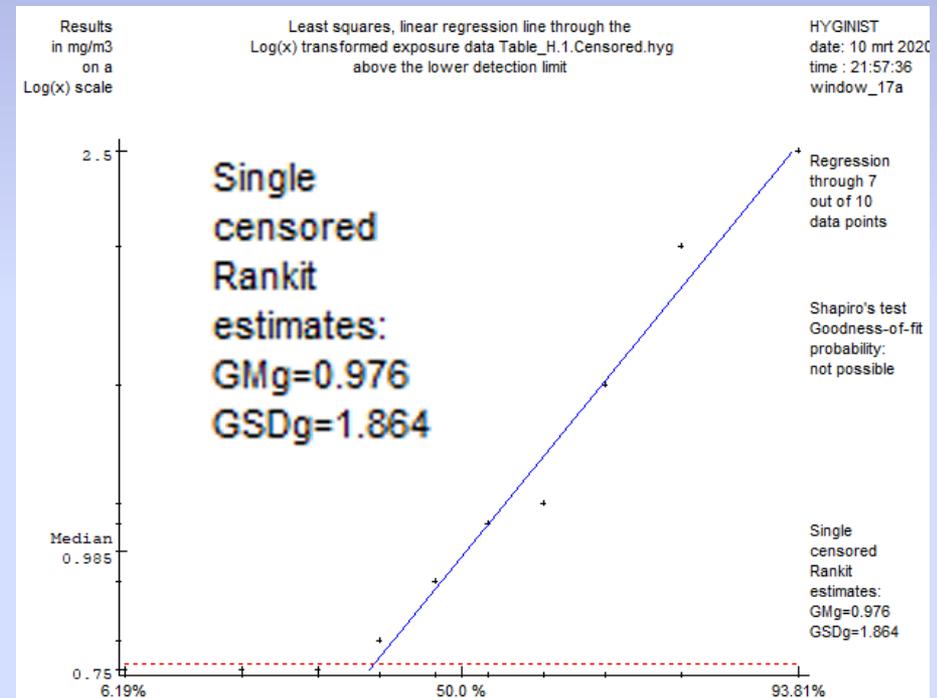
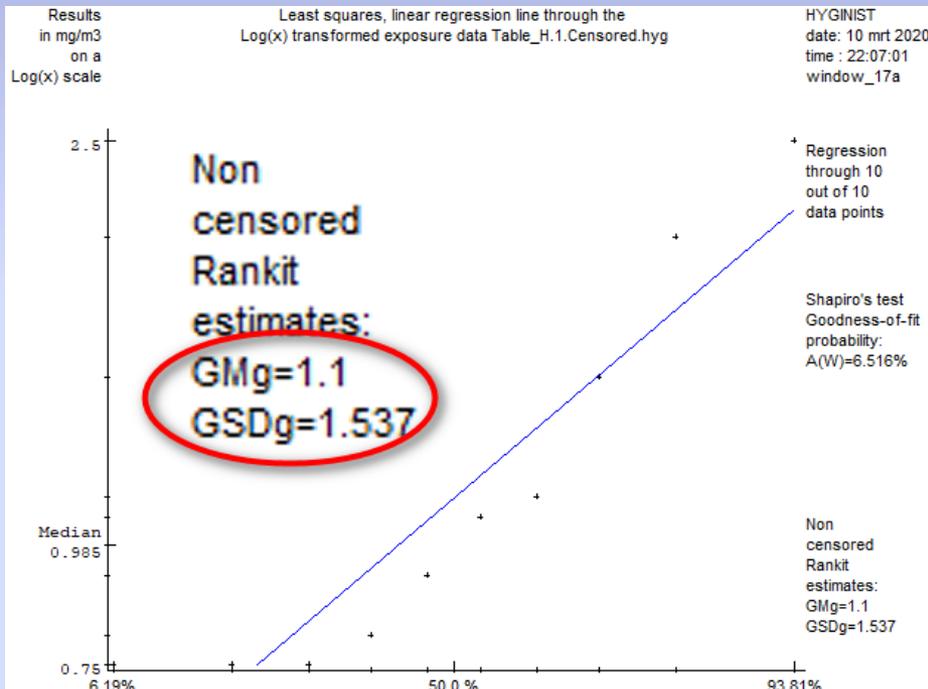




Annex H Table 1 met 3 LoQ's

Geen detectiegrens

Met detectiegrens



$$C_{95,70\%} = 2.6 \text{ mg/m}^3$$

$$C_{95,70\%} = 3.5 \text{ mg/m}^3$$

Annex H (informative) Exposure below the limit of quantification (LoQ)

EN 689:2018 (E)

Annex H (informative)

Exposure below the limit of quantification

H.1 General

Annex H gives a procedure to handle exposures that are below the limit of quantification (LOQ) when the statistical test given in 5.5.3 is used.

H.3 Example

In this illustration, it is assumed that all the exposure measurements, including those below LOQ approximate to a lognormal distribution (see Annex E). In this example, the LOQ is 0,75 mg/m³. Measurements were made until seven measurements gave results above LOQ. In the course of this, three results were obtained which were less than 0,75 mg/m³. The results are shown in Table H.1 arranged in rank order. Figure H.1 shows the results as a log-probability plot, and the closeness to a straight line for the values above LOQ illustrates that they are lognormally distributed. The three values below LOQ are plotted with a symbol \ominus at the LOQ. In reality of course, they should appear at unknown positions at lower values of exposure, and they cannot be used to estimate the best line through the other points. The plotted

Number N of measurements	Limiting value of U_T for $C_{95\%,70\%}$
1	
2	4.21677
3	2.80912
4	2.45308
5	2.28592
6	2.18677
7	2.12007
8	2.072
9	2.035
10	2.005
11	1.981
12	1.961
13	1.944
14	1.929
15	1.917
16	1.905
17	1.895
18	1.886
19	1.878
20	1.870

Welk aantal LoQ's doet mee U_R tegen U_T te toetsen?
(Niet in EN689).

Aanbeveling: neem ze voor de helft mee (HYGINIST)

LoQ correcties

Annex H table 1 10 metingen met 3 LoQ	GM	GSD	$C_{95,70\%}$
Doe niets (df=9)	1.1	1.5	2.6
Verwijder de 3 LoQ (df=6)	1.3	1.5	3.2
0.5*LoQ (df=9)	0.9	2.0	3.6
BWSTAT (df=9)	0.9	2.0	3.4
HYGINIST (df=7)	1.0	1.9	3.5

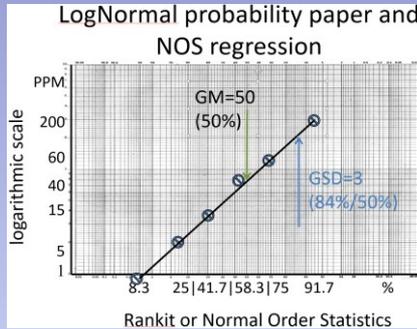
'Doe niets' en 'Verwijder' 0.5*LoQ:
GM en GSD onzuivere schatters

Indien (bijna) alle metingen $< \text{LoQ}$

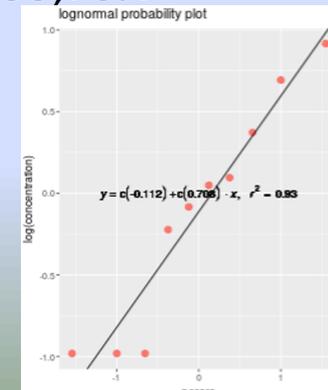
Suggesties (nog geen sheets):

- binomiaal (> 20 metingen)
- Met een default GSD

Meeneemboodschap LoQ



- (log)Normaal 'papier'
 - GM : mediaan =50%
 - GSD: 84%/50%
- Negeren of verwijderen van LoQ's is systematisch fout
- Substitutie $f(\text{LoD}) \Rightarrow$ onzuivere schatting $C_{95,70\%}$





Software

1. [BWStat online](#), [Altrex Chimie](#), IHSTAT, IHDA-S ($N \leq 25$), [EXPOSTATS](#) werken alleen met <waarden
2. HYGINIST
 - het (log)normale deel van de meetserie
 - opimaliseren met Shapiro&Wilk
3. IHSTAT met NDEXPO berekent geen $C_{95,70\%}$

Verdieping & Aanvullingen

1. Maatschappelijk draagvlak
2. NL definities en begrippen

Efficiency/betrouwbaarheid vergroten:

3. Inzoomen op het hoogste risico.
4. EN 689 priors(2)
5. Aanvullende priors
6. Online tools
7. Bruikbaarheid buiten (EU) Arboregelingen

Application of EN689 prior GSD knowledge 4.

- I. Preliminary test (§5.5.2)
- II. Validation of results and SEG (§5.4)
- III. Optimize sample size (§5.3 & 7)



Betrouwbaarheid preliminary test

Gecorrigeerde preliminary test (§ 5.5.2)

5.5.2 a):
niet <0,##
maar ≤ 0,##

Alle resultaten: ≤ 0,10 (10%) GW voor 3 metingen ≤ 0,15 (15%) GW voor 4 metingen ≤ 0,20 (20%) GW voor 5 metingen	Compliance 5.5.2 a) 1-3
1 resultaat > GW	Non-compliance 5.5.2 b)
Alle resultaten < GW, maar ≥ 1 is: > 0,10 (10%) GW (voor 3 metingen) of > 0,15 (15%) GW (voor 4 metingen) of > 0,20 (20%) GW (voor 5 metingen)	Geen beslissing 5.5.2 c) / conclusie
Aanvullende metingen (tot minimaal 6) + statistische toets (5.5.3): <5% grenswaarde overschrijding met 70% zekerheid, of 5% grenswaarde overschrijding met ≥ 70% zekerheid	

5.5.3: schrijft
onjuist
≥70% dat <5%

5.5.2 c):
niet één
maar ≥ 1

preliminary test is conservatief voor $C_{95\%} \leq OELV$:

- Werkgever, bij $GSD < 2$ (>75% vals positieven, bruin + rood)
- Blootgestelde, bij $GSD > 4$ (>50% vals negatieven, groen)

Preliminary test (§5.5.2)

Validation study INRS ND2231 (2005)

$$LV = C_i / OELV$$

Sample size

GSD

TABLEAU V

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 0.05.

Nombre de mesures	Écart-type géométrique					
	1,1	1,5	2	2,5	3	4
3	0,92	0,70	0,54	0,45	0,38	0,30
4	0,93	0,75	0,61	0,52	0,46	0,37
5	0,95	0,79	0,67	0,59	0,53	0,45

Confidence to find non-decision/compliance ~70% for GSD~4
Confidence increases if GSD decreases and vice versa.
So, preliminary test requires prior knowledge on GSD !!

$$C_i / OELV$$



Aanvulling op preliminary test

1. Toets 2-5 metingen óók statistisch $C_{95,70\%} \leq \text{OELV}$ (§5.5.3)
 2. Zoek in de basiskarakterisering de verwachte GM en GSD (§ 5.1.4)
- Evalueer verschillen & overeenkomsten

Application of prior GSD knowledge

- I. Preliminary test (5.5.2)
- II. Validation of results and SEGs (5.4)
- III. Optimize sample size (5.3 & 7)



4.II Validation of results and SEGs (§5.4)

A. Check homogeneity within a SEG

Verschillen/overeenkomsten binnen/tussen SEG's

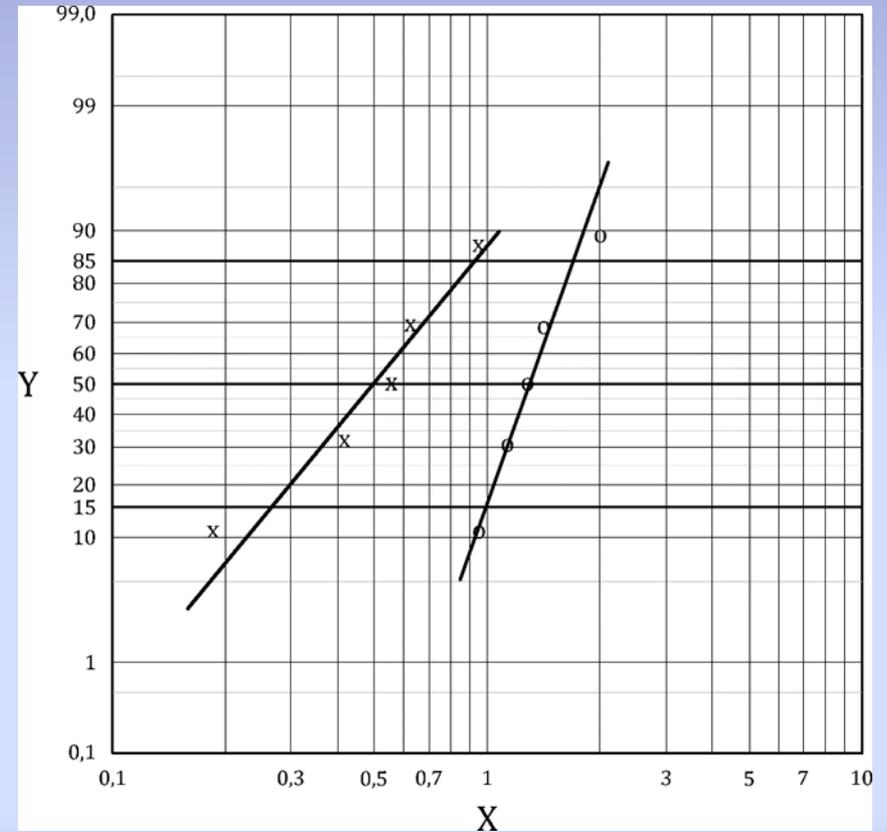
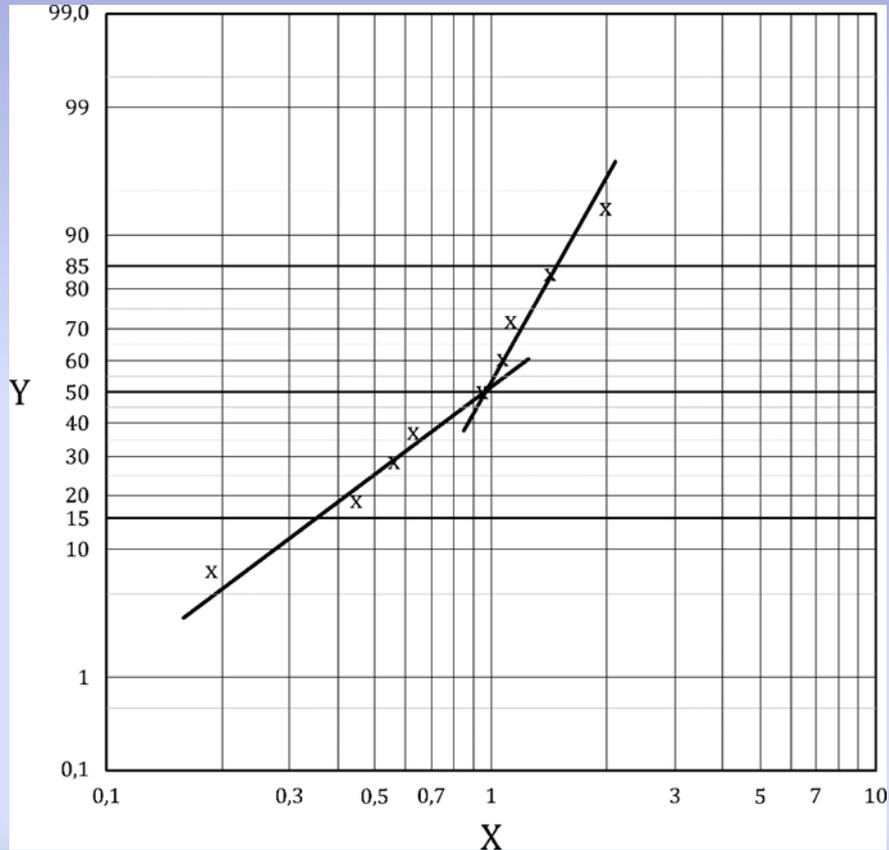
5.4.3 Validation of SEGs *“An important complication is that two workers doing the same job may not have the same exposure. This phenomenon, known as between-worker variability, means that measurements of one worker’s exposure cannot simply be assumed to apply to others doing nominally the same job.”*

Meer algemeen:

Welke werknemers/locaties/activiteiten kunnen samengevoegd worden in één SEG of welke SEG's moeten worden opgesplitst?

Homogeneity & heterogeneity

2 SEG's? Annex E.2.4.2



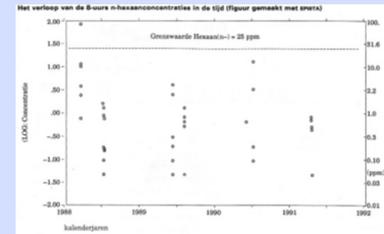
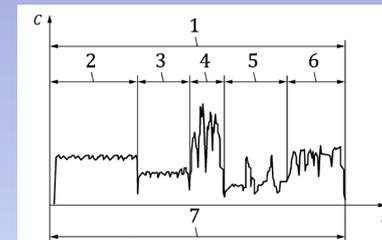
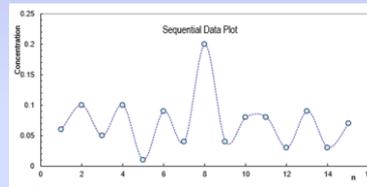
BOSH-NVvA (2011) variantie analyse

Homogeneity within a SEG

BOHS NVvA (2011) A 1.2 ANOVA

Verschillen in een SEG

- taken tijdens een dienst
- Personen
- weekdays
- Seizoenen
- Locaties



Wat is variantie analyse?

Onderzoek naar verschillen binnen een populatie in:

- spreiding ($GSD_{i \dots n}$ =variantie)
- **gemiddelden ($GM_{i \dots n}$)**
- (log-)normale vorm

Alle drie (GM, GSD, Vorm)!



BOHS NVvA (2011) A 1.2 ANOVA

*Testing Compliance with
Occupational Exposure Limits
for Airborne Substances*



British Occupational Hygiene Society
Pride Park Derby
DE24 8LZ, UK
www.bohs.org

September
2011



Nederlandse Vereniging voor
Arbeidshygiëne
Postbus 1762,
5602 BT Eindhoven
The Netherlands
www.arbeidshygiene.nl/

Originally published September 2011
This edition December 2011
See p51 for amendment history

Homo/hetogeneity within a SEG BOHS NVvA (2011) A 1.2 ANOVA

The screenshot displays an Excel spreadsheet with the following data:

	Greg	Joe	Chloe
Mon	0.16	0.51	0.18
Tue	0.38	0.60	
Wed	0.20	0.35	
Thur	0.44	0.70	0.65

The 'Joe' column values (0.51, 0.60, 0.35, 0.70) are circled in red.

The ANOVA results are as follows:

Groups	Count	Sum	Average	Variance
Column 1	4	-5.23058	-1.30765	0.239707
Column 2	4	-2.60024	-0.65006	0.089071
Column 3	2	-2.15083	-1.07542	0.817619

The ANOVA table also includes the following values:

Source of Variator	SS	df	MS	F	P-value	F crit
Between Groups	0.879759	2	0.43988	1.706894	0.249008	4.737414
Within Groups	1.803954	7	0.257708			
Total	2.683713	9				

The P-value (0.249008) is circled in red.

The results of the Analysis of Variance.

Homogeneity within a SEG

BOHS NVvA (2011) A 1.2 ANOVA

BWStat v3



Enter substance name:

Cottondust

value	worker	date	detect
0.16	greg	mon	TRUE
0.38	greg	tue	TRUE
0.20	greg	wed	TRUE
0.44	greg	thur	TRUE
0.51	joe	mon	TRUE
0.60	joe	tue	TRUE
0.35	joe	wed	TRUE
0.70	joe	thur	TRUE
0.18	chloe	mon	TRUE
0.65	chloe	thur	TRUE

Data entry

Graphical results

Numerical results

Download

BWStat

IHStat

Object of class BWStat
10 measurements, 3 workers

No significant differences between workers, individual compliance test not required.
Homoscedastic: Yes

Between group variance: 0.05811074

Within group variance: 0.257336

Total variance: 0.3154467

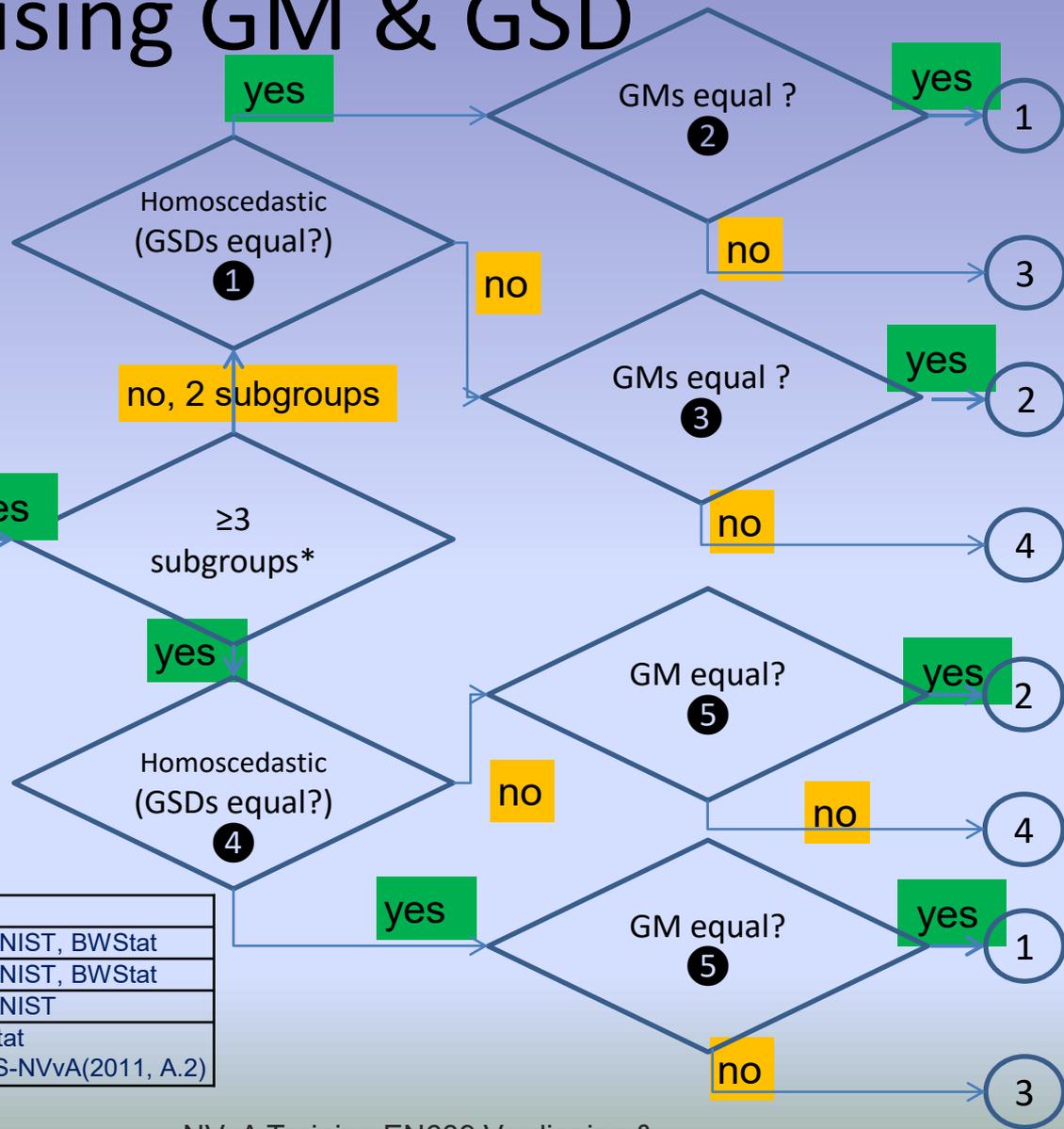
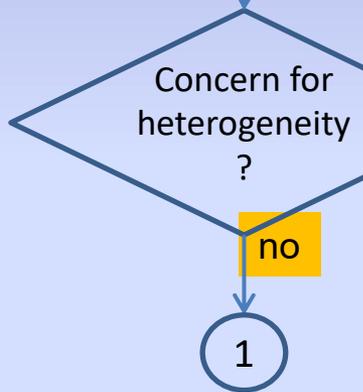
F value: 1.722613

Critical F value: 4.737414

P value: 0.2463943

Testing SEG homogeneity using GM & GSD

Basic characterization,
Outliers,
(Log-)Normal Plots

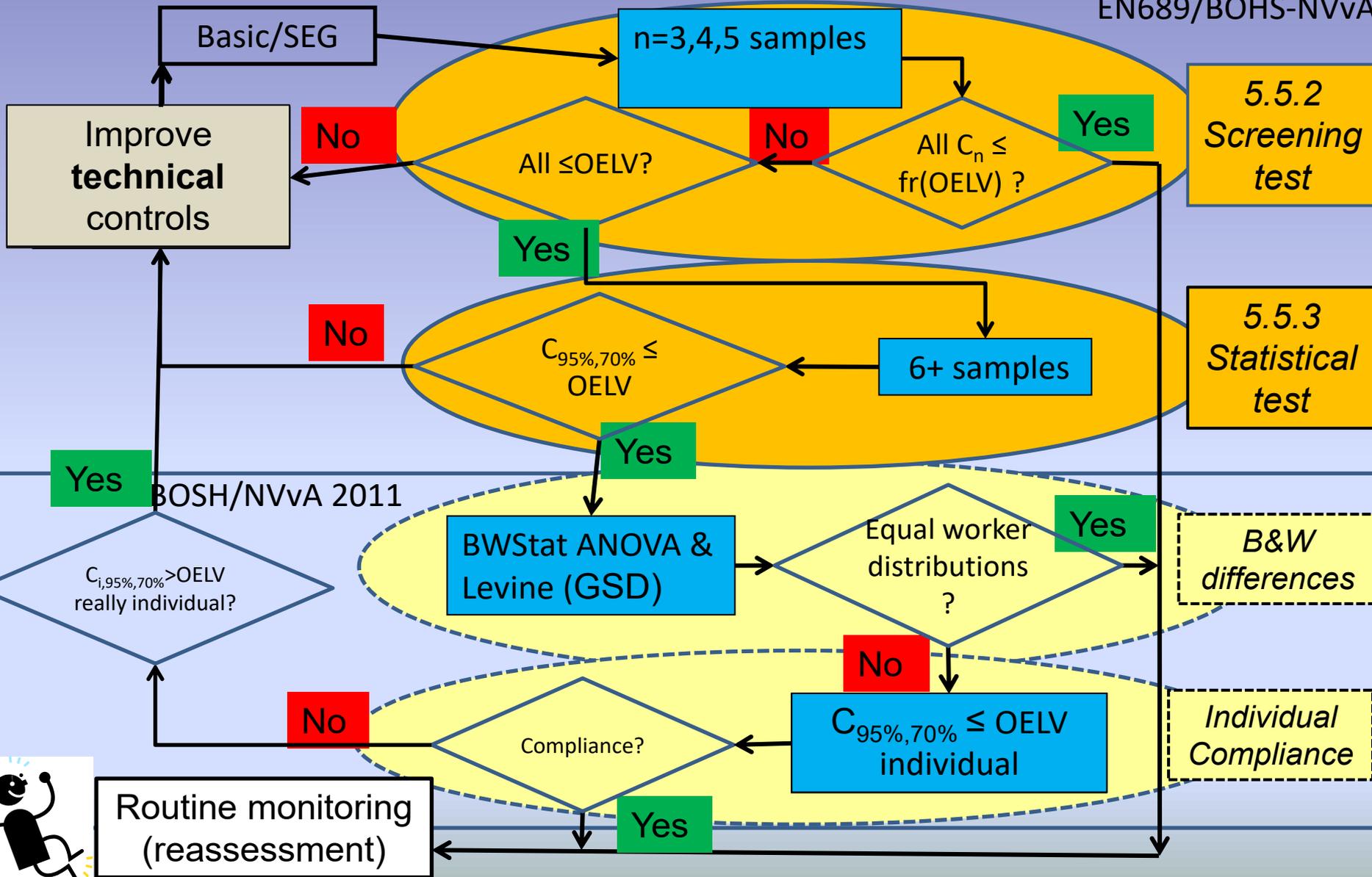


- decisions
- ① SEG valid
 - ② Reassess variability/GSD
 - ③ Reassess Level/GM
 - ④ Reassess GSD & GM

test	Method	Snedecor	App's
①	F-test	6.12	HYGINIST, BWStat
②	t-test	6.5	HYGINIST, BWStat
③	Welch/Aspin t-test	6.11	HYGINIST
④	Heteroscedasticity	13.11	BWStat
⑤	One-way ANOVA	12.2	BOHS-NVvA(2011, A.2)

689/NVvA-BOHS testing scheme

EN689/BOHS-NVvA



Homogeniteits analyse in de praktijk

(Te) veel aandacht voor:

- (Kleine) verschillen tussen personen

(Te) weinig gebruikt voor :

- Verschillen tussen locaties, taken, beheersregimes
- Identificeren worst-case
- Combineren van personen/locaties in 1 SEG
- Combineren meerdere belastende factoren in 1 SEG

Verschillen tussen personen (§5.4.3)

“individuals performing the same job in the same location might, more often than not, have considerably different average exposures”.
Kromhout (2016)

“.. earlier convincing publications (Kromhout et al., 1993, Symanski et al., 2006)”



No two workers are exposed exactly the same

2011

Testing between worker
differences



But are BW
differences
strong?

verschillen tussen personen in HEG's

Dear Sir:
 We read with interest the thoughtful letters from Cole, Gomez, and Scheffers regarding the article, "Variation of Exposure Between Workers in Homogeneous Exposure Groups."⁽¹⁾ Since we had hoped to provoke a debate on the concept of homogeneous-exposure groups or HEGs, it was gratifying to see such interest in our paper.

iation in HEGs. Focusing first on the lower limits, we can say with confidence that 30% of the groups were not "homogeneous," since these lower limits correspond to values of $B\hat{R}_{.95} > 1$. Like-

S.M. Rappaport, Ph.D.
 E. Symanski
 R. Lyles
 University of North Carolina
 H. Kromhout, Ph.D.
 Wageningen Agricultural University

AM. IND. HYG. ASSOC. J. (53) / September 1994

$B\hat{R}_{.95} > 1$
 85% →

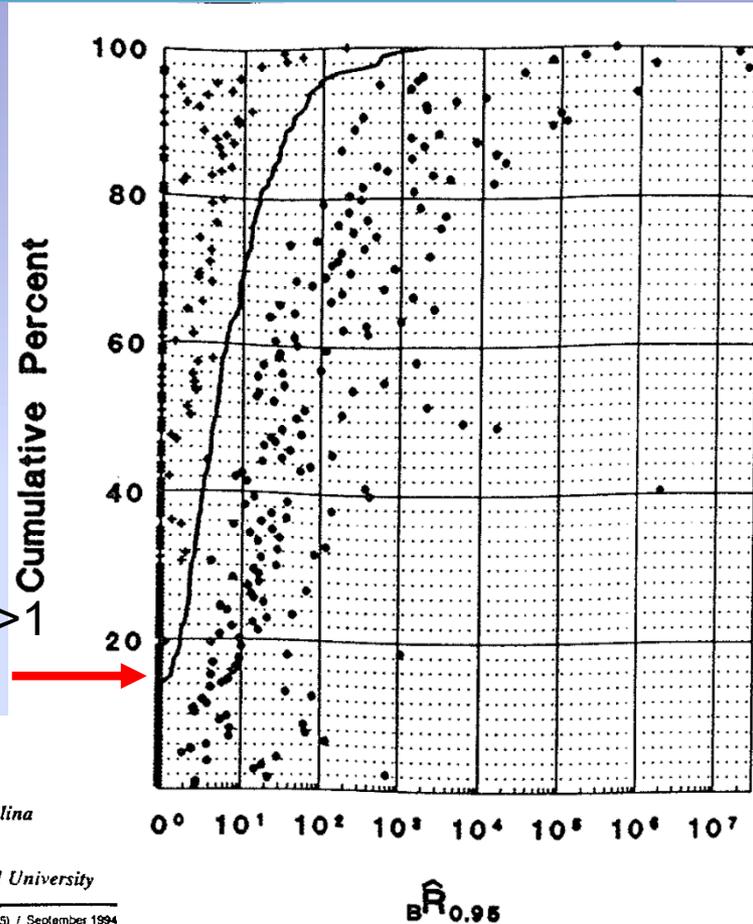


FIGURE 1. The solid curve depicts the empirical cumulative distribution function of $B\hat{R}_{.95}$ for 183 HEGs.⁽¹⁾ Individual points represent lower (+) and upper (•) bounds on a 95% confidence interval for $B\hat{R}_{.95}$ for each group.

Verschillen tussen personen in HEG: “more not than often”

~30% significant, echter

- Modelmatige exercitie $\beta R_{.95}$, pseudo ANOVA
- BI met benadering methode berekend
- $0.5 * LoQ$ gebruikt voor undetectables
- Geen ‘lognormal goodness-of-fit’ beoordeling

- Short-term campaigns: onderschatting van dag tot dag spreiding?
- periodieke taak roulatie niet meegenomen: overschatting verschillen tussen personen
- HEG ipv SEG strategie?
- Meetseries uit de jaren 70 en 80 (minder multi-tasking)

Bij herevaluatie (Symanski, 2006) zijn veel onbetrouwbare datasets verwijderd

Conclusie:

Verschillen bestaan, maar “more not than often”

SEGs over meerdere locaties (1)

5.2.1 Constitution of Similar Exposure Groups (SEGs)

“If a SEG includes workers from different locations, care shall be taken that the SEG meets the definition in clause 3.1.3 of this European Standard.”

5.2.2 *“... workers in a SEG belong to different locations.. “*

Ochtend voorbeeld 3: meer SEGs?

Verschillende
lijnen, zelfde
SEG?

Taak	Datum	Blootstellingsindex oplosmiddelen (B.I.) (Tier 1)
Afvullen lijn 1	16-10-2019	0,0021
Afvullen lijn 2	16-10-2019	0,0047
Afvullen lijn 3	05-12-2019	0,00016
Afvullen lijn 5	16-10-2019	0,05

Metingen
op 2 dagen

Is dit één SEG?
BWStat/ANOVA met meer metingen



SEGs over meerdere locaties (2)



Abstract—Personal exposure to solvents was studied among hairdressers in 28 salons in two regions during two seasons in The Netherlands. Ethanol was used as a marker for solvent exposure. Auxiliary data, such as salon and work characteristics, meteorological conditions and information on the presence of control measures, were collected during the measurements. The average exposure to ethanol was almost a factor of 200 below the occupational exposure limit, but differences in average ethanol concentrations up to a factor of 30 were present between salons. Exposure concentrations were significantly higher on Fridays than on other days of the week. Contrary to expectation, exposures were somewhat lower in the spring than in the summer and in an urban than a semi-rural area. An empirical statistical model based on exposure data collected during the first measurement period appeared not to be valid for the encountered circumstances in the second measurement period. An alternative classification scheme based on two easily obtainable salon and task characteristics was elaborated. This scheme will be applied in an ongoing epidemiological study on reproductive disorders among hairdressers and their offspring. © 1997 British Occupational Hygiene Society. Published by Elsevier Science Ltd.

aanbeveling

NVvA (via EU platform)

meer onderzoeks aandacht naar verschillen èn overeenkomsten binnen en tussen SEG

Moet je de SEG splitsen of kun je meerdere SEG's ook gevalideerd samenvoegen?

SEGs over meerdere locaties (3)

Ann. Occup. Hyg., Vol. 50, No. 1, pp. 55–64, 2006
© 2005 British Occupational Hygiene Society
Published by Oxford University Press
doi:10.1093/annhyg/mei041

Are Variance Components of Exposure Heterogeneous Between Time Periods and Factories in the European Carbon Black Industry?

MARTIE VAN TONGEREN^{1,2*}, IGOR BURSTYN^{3,4}, HANS KROMHOUT⁴
and KERRY GARDINER^{2,5}

In total, 5296 measurements from 1771 workers were available collected during two surveys carried out between 1991 and 1995. Workers were grouped into eight job categories, and for each of these separate mixed-effects models were developed, including factory, survey and in some cases the interaction term as the fixed effects. The likelihood ratio test was used to test the assumptions of homogeneity of the variance components. Statistically significant heterogeneity of the variance components was observed for two of the eight job categories, 'Fitter/Welder' and 'Warehouseman'. The heterogeneity was due mainly to differences in variance between the factories. When estimating the probability of overexposure for all the

Software

IH **Freeware** voor check op SEG homo/hetrogeniteit

1. BWStat (≥ 2 factoren)
2. HYGINIST (2 factoren)

Baysiaans

[EXPOSTATS](#), [Altrex Chimie](#) (?)

Niet

IHSTAT, IHDA-S



Application of prior GSD knowledge

- I. Preliminary test (5.5.2)
- II. Validation of results and SEG (5.4)
- III. Optimize sample size (5.3 & 7)



4.II Validation of results and SEGs

B. Variability & 'typical'

4.II.B. variabiliteit

EN689 Introductie

“Representative measurement of occupational exposure to chemical agents is difficult, because of the variability of exposure.”

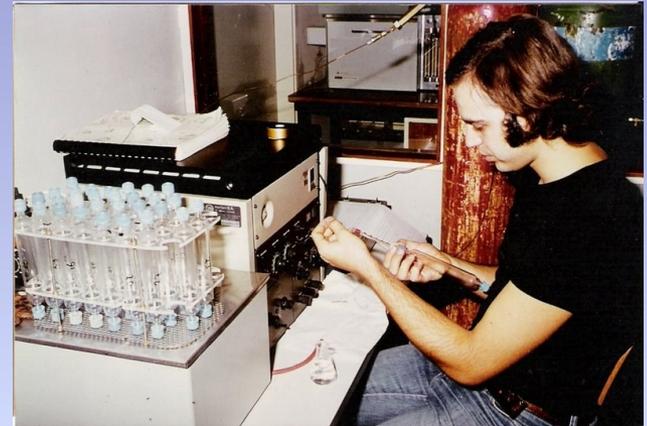
*“Het representatief meten van beroepsmatige bloot-stelling aan chemische agentia is moeilijk vanwege de **variabiliteit** van de blootstelling”*



variability of workplace exposure

EN 689

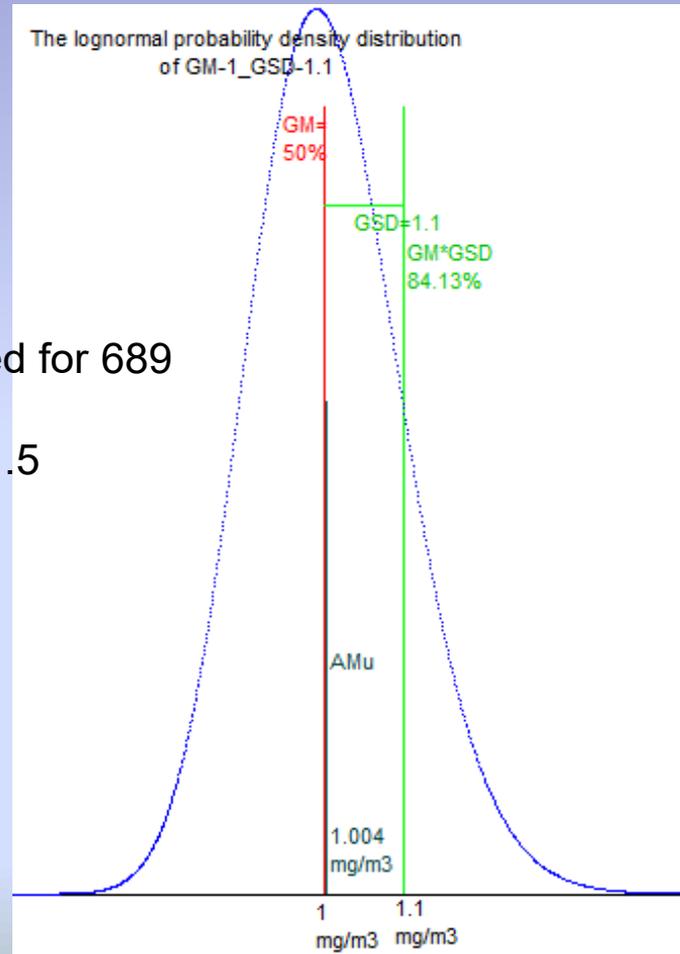
- Measurement
 - Sampling
 - Analytical
- Workplace and external factors
 - substance physchem properties
 - Worker activities
 - Organization
 - Controls
 - Climate, weather



Measurement variability 5.2.2

Sampling and analytical variability:

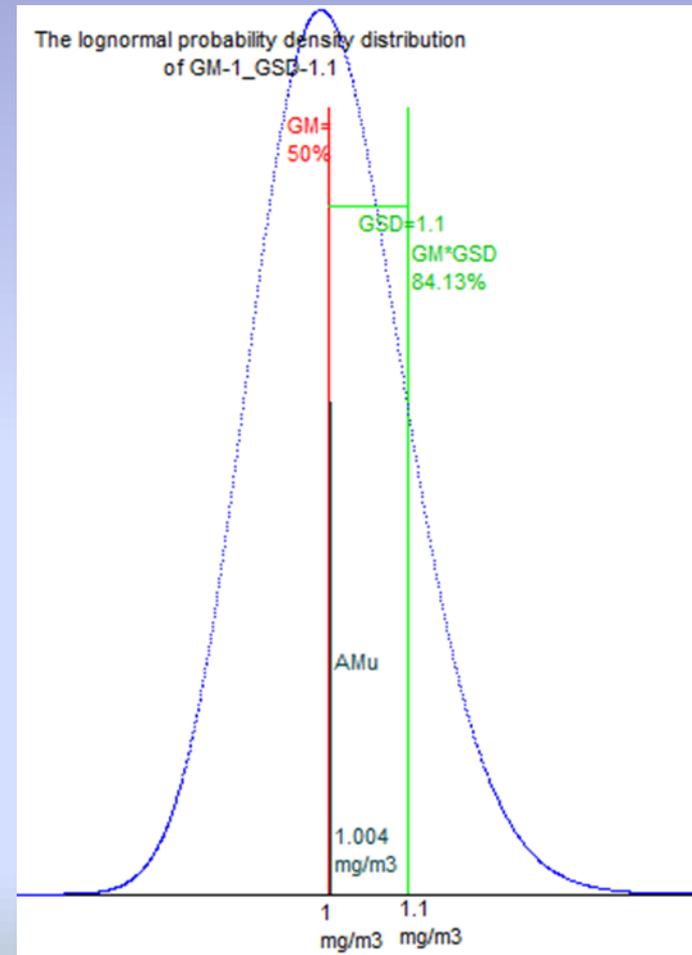
- Random errors, otherwise rejected for 689
- Normal distribution
- CV_t EN482 $\ll 50\%$ \Rightarrow $GSD \ll 1.5$



Meeneemboodschap

Ontbreken werkplekfactoren dan (Annex E.1):

- Wordt de spreiding in de uitkomsten bepaald door de meetfouten
- Is de verdeling Normaal (Gaussian)



Lower limit of the GSD

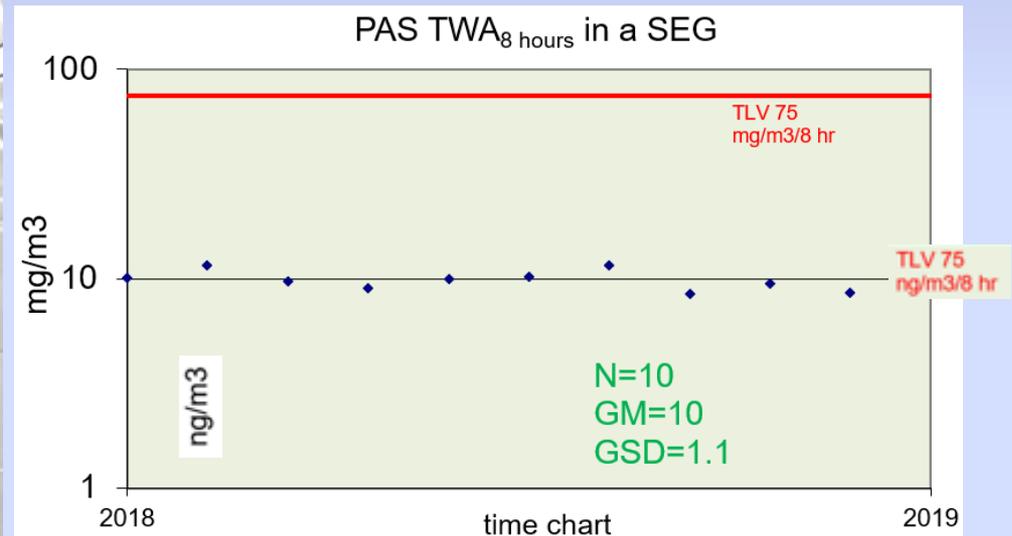
Leidel & Busch NIOSH 77-1173 p 124

above represent relatively high variation. Hald (M-22) states that the shape of lognormal distributions with low variations, such as those with *GSD*'s less than about 1.4, roughly approximate normal distribution shapes. For this range of *GSD*'s, there is a rough equivalence between the quantity $(GSD - 1)$ and the *CV*, as follows:

<u><i>GSD</i></u>	<u>$(GSD - 1)$</u>	<u><i>CV</i></u>
1.05	0.05	0.049
1.10	0.10	0.096
1.20	0.20	0.18
1.30	0.30	0.27
1.40	0.40	0.35

Variability in a well controlled workplace

Predominantly caused by measurement itself



Wanneer toets je in 5.5.3 met de normale verdeling?

Indien

- De vorm normaal is èn
- Er geen werkplekfactoren zijn die de blootstelling beïnvloeden:
 - $GSD \sim 1 + CV$ of
 - Constante achtergrond overheerst
 -

Workplace variability

“Processes and products affecting exposure are numerous”.

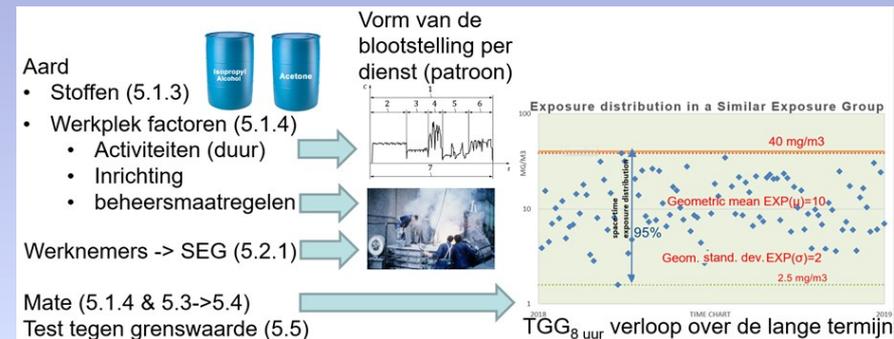
workplace conditions:

- generation rates,
- a variety of chemical agents
- specific exposure conditions

Exposure affected by:

- distance exposed worker <> emission sources
- emission intensity, ventilation, climatic conditions, seasonal variations and the controls applied.

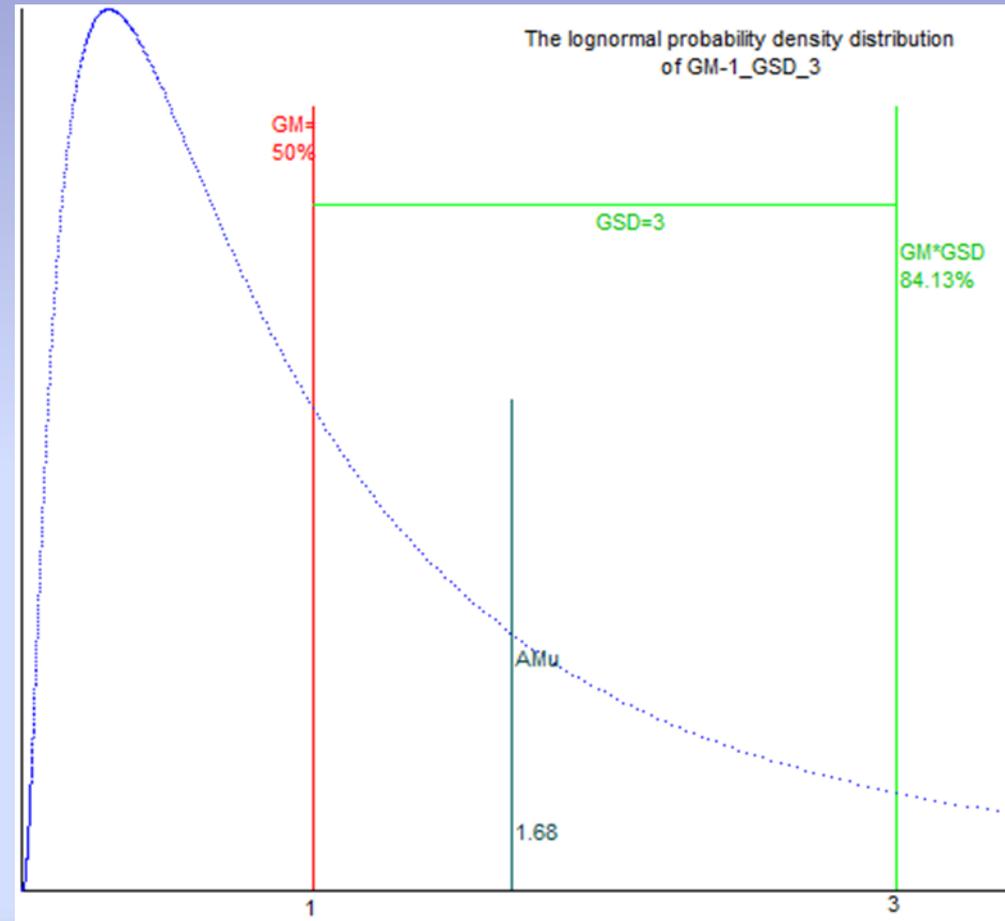
The spatial and temporal variabilities of exposure are further enhanced by the workers' practices and activities themselves.



Meeneemboodschap

De multiplicatieve interacties van werkplekfactoren op de blootstelling:

- maken de verdeling log-Normaal (Annex E.1)
- Overschaduwten snel de meetfout CV_t (EN482 accepteert $CV_t=30\%/50\%$)





Wanneer toets je in 5.5.3 met de lognormale verdeling?

Indien

- vorm lognormaal
- werkplekfactoren in het blootstelling profiel bepalen het blootstelling patroon
- meetfouten en achtergrond emissies zijn ondergeschikt

Of

- Indien normal en lognormaal beide passen (conservatief)

Variabiliteit: (Oorzaak en) omvang

Representatie spreiding ('typical')?

5.2 & Annex E2.4.2.

“Non typical variability of the results (too large or too small) can indicate that the sampling strategy is not valid or representative (clause 5.2).”

This can be checked against what is normal in literature or in databases like MEGA or SCOLA using the tests described in E.3.”

“Niet typische spreiding van de resultaten (te groot of te klein) kan erop wijzen dat de meetstrategie niet geldig of representatief is (clausule 5.2).”

Literatuur en Modellen GSD

Model	GSD
StM®	5.4
ART	2.4

Databases (nog) niet presentatie

Nu: professional judgement

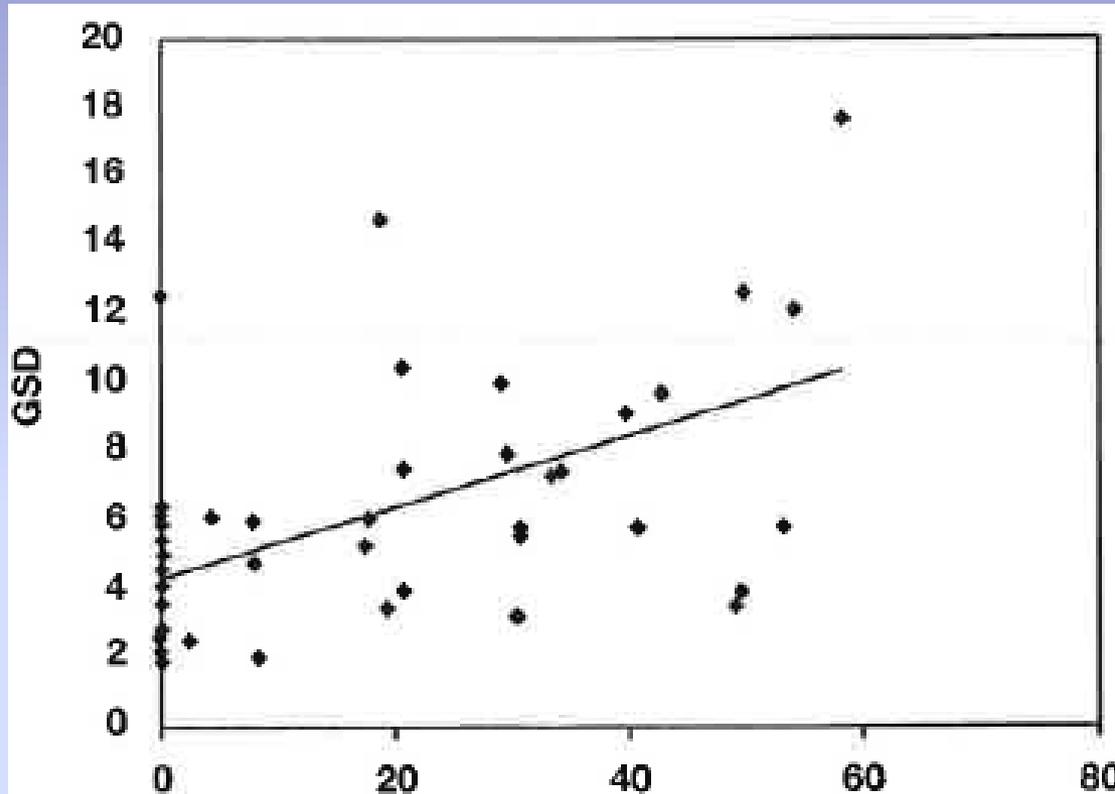
Operational Conditions (OC) & exposure variability

Low GSD	High GSD
Clean room, well controlled industrial OC	Outdoor, Professional OC
Worst-case/single task	multiple tasks in a SEG
High background level	No background inference

Strategy & exposure variability

Low GSD	High GSD
Short sampling campaign (1 day, one week): autocorrelation, missing tasks	Long-term, mutually independent sampling campaign (months, year)
EM	PAS
Small sample size ($N \leq 6$)	Large sample size
Small detection range (Gravimetric, inorganic acids)	Broad detection range (Analytical: AAS, DPP, IC, EC, etc.)
Fixed factor or remove undetectables	Correct handling undetectables

Perc. non-detects increases with GSD



long-term GSD in chemical industry

Tijdschrift voor toegepaste Arbowetenschap 13 (2000) nr 4

T.M.L. Scheffers¹, J. Marquart², J.J. Twisk³

Why GSD is often underestimated in exposure assessment (2)

- Small sample size: series of 2 to 6 measurements underestimate the GSD on the average
- Short sampling program during one or some consecutive days: autocorrelation and limited temporal variability
- Use of old-time data (databases) with single task workers had 1

GSD

$$GSD = \text{EXP}(s)$$

$$s = \sqrt{\frac{\sum_{i=1}^M (x_i - \bar{x})^2}{M-1}}$$

M sample size, X_i log(concentration)

Typical exposure variability

Welke spreiding (GSD) is 'typical' ?

1. GSD<3
2. GSD<5.3
3. GSD<14
4. Een GSD is een eigenschap van een blootstellingsprofiel



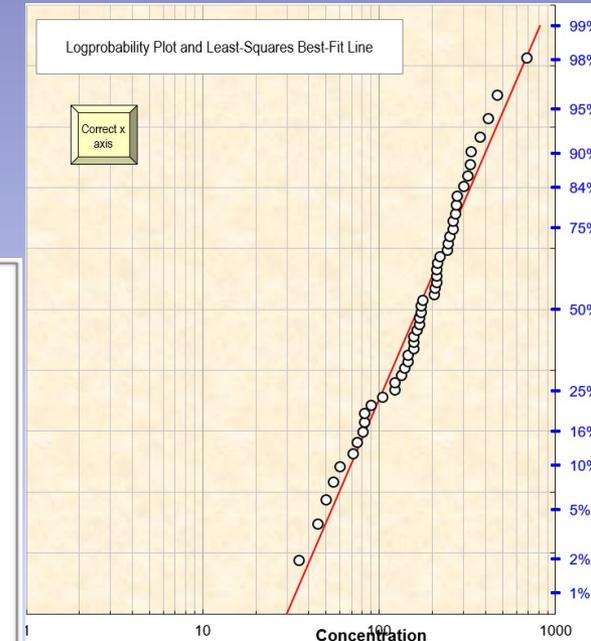
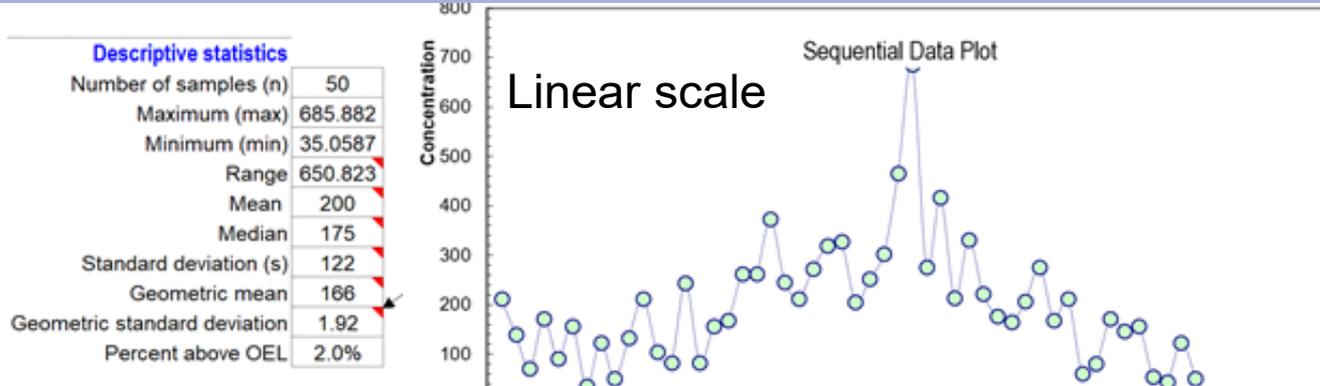
GSD and measurement methods

GSD's based on detection range

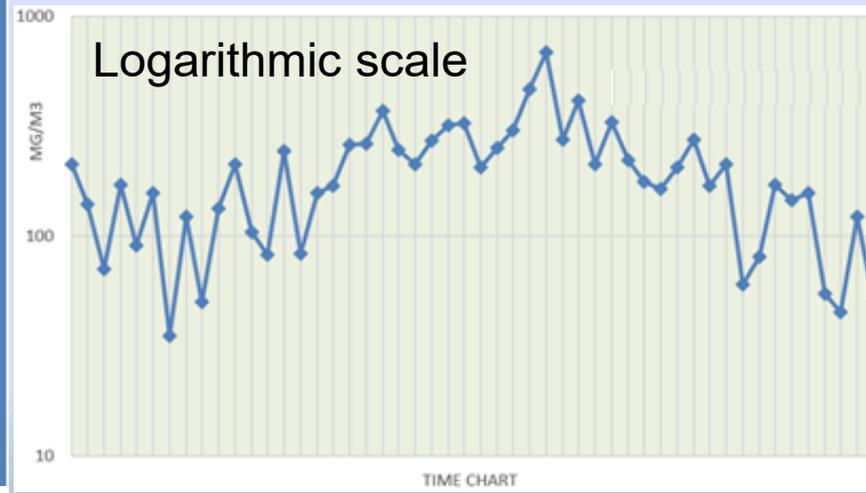
- GSD=1,5 $0,5 \leq TI_{95\%} \leq 2$ (inorg. acid mist)
- GSD=2 $0,3 \leq TI_{95\%} \leq 3$ (gravimetric)
- GSD=3 $0,16 \leq TI_{95\%} \leq 6$ (analytical:
- GSD=4,1 $0,1 \leq TI_{95\%} \leq 10$ halogens,
- GSD=5,4 $0,07 \leq TI_{95\%} \leq 14$ metals,
- GSD=11 $0,02 \leq TI_{95\%} \leq 50$ P, N, S and
- GSD=17 $0,01 \leq TI_{95\%} \leq 100$ solvents)

GSD and time

IHSTAT



GM₀₁₋₁₀=104	GSD₀₁₋₁₀=1.78
GM₁₁₋₂₀=174	GSD₁₁₋₂₀=1.69
GM₂₁₋₃₀=307	GSD₂₁₋₃₀=1.45
GM₃₁₋₄₀=235	GSD₃₁₋₄₀=1.36
GM₄₁₋₅₀=95.5	GSD₄₁₋₅₀=1.78
GM₀₁₋₅₀=166	GSD₀₁₋₅₀=1.92



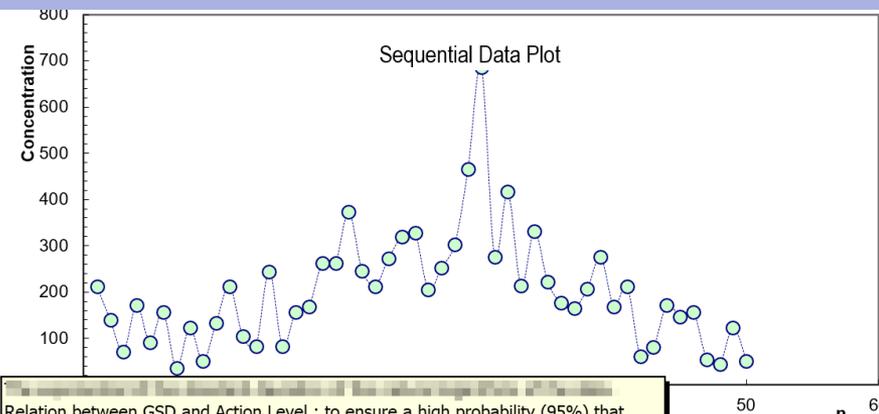
'Typical' archaic GSD statement

IHSTAT

Descriptive statistics

Number of samples (n)	50
Maximum (max)	685.882
Minimum (min)	35.0587
Range	650.823
Mean	200
Median	175
Standard deviation (s)	122
Geometric mean	166
Geometric standard deviation	1.92
Percent above OEL	2.0%

Test for distribution fit



Relation between GSD and Action Level : to ensure a high probability (95%) that no more than 5% of unmeasured exposures exceed the OEL, the Action Level, must be lowered as the GSD increases, as follows: day-to-day variability, GSD ≤ 1.3, OEL = 0.5 TLV; GSD = 1.5, OEL = 0.25 TLV; GSD = 2.0, OEL = 0.1 TLV; GSD ≥ 3.0, Process out of control or group poorly defined. (Leidel, 1976)



GSD ≥ 3.0, Process out of control or group poorly defined. (Leidel, 1976)

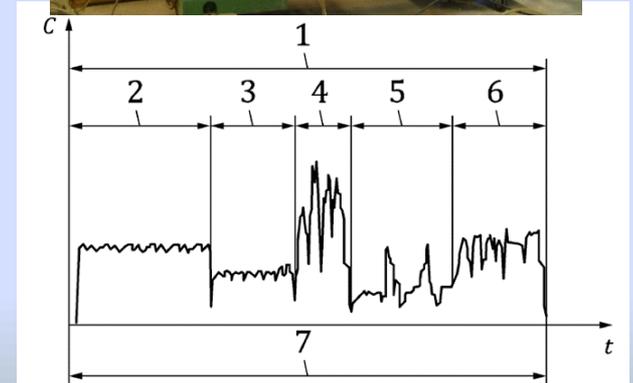
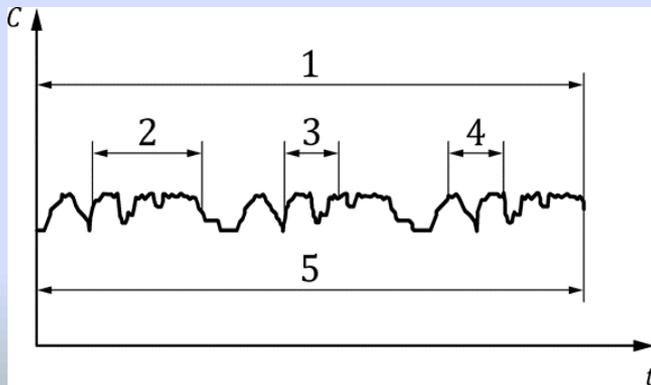
'Typical' archaic GSD statements

GSD ≥ 3.0 , Process out of control or group poorly defined. (Leidel, 1976)



<1975: 8hrs single task,
constant conditions (A.2.a)
GSD<3

Multiple tasks(A.5) >1975
GSD ≥ 3



GSD outdoor painting

Which exposure pattern is typical for this exposure profile?
Long-term $TWA_{8\text{hours}}$ outdoor hydrocarbon solvent based painting

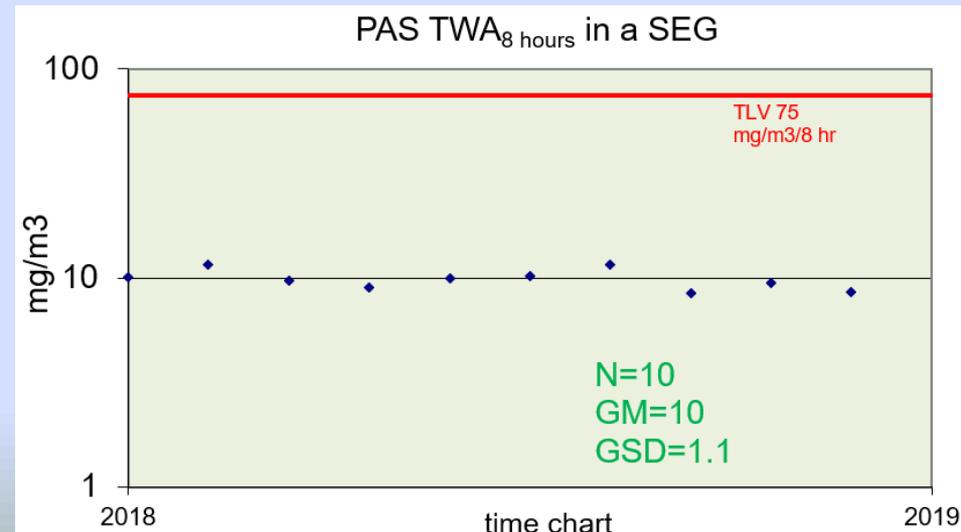
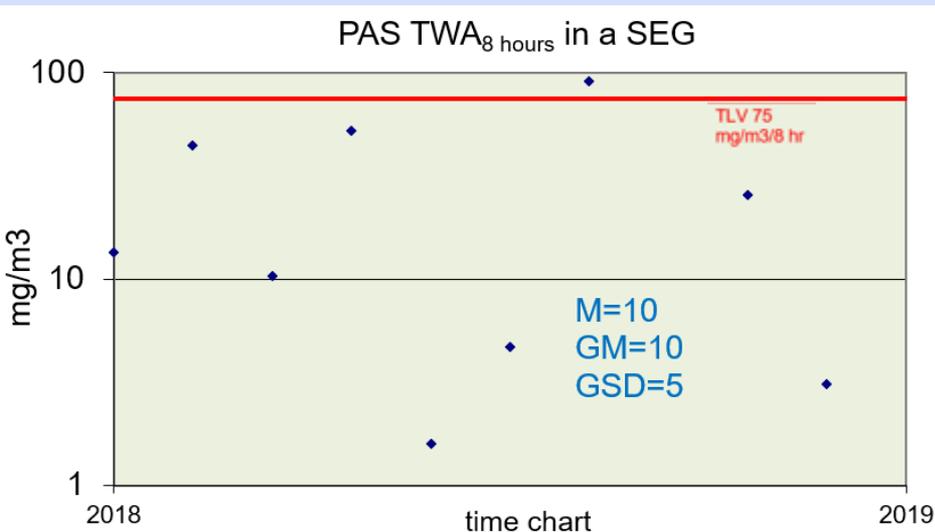
A

GSD
large



B

GSD
small



GSD pharma

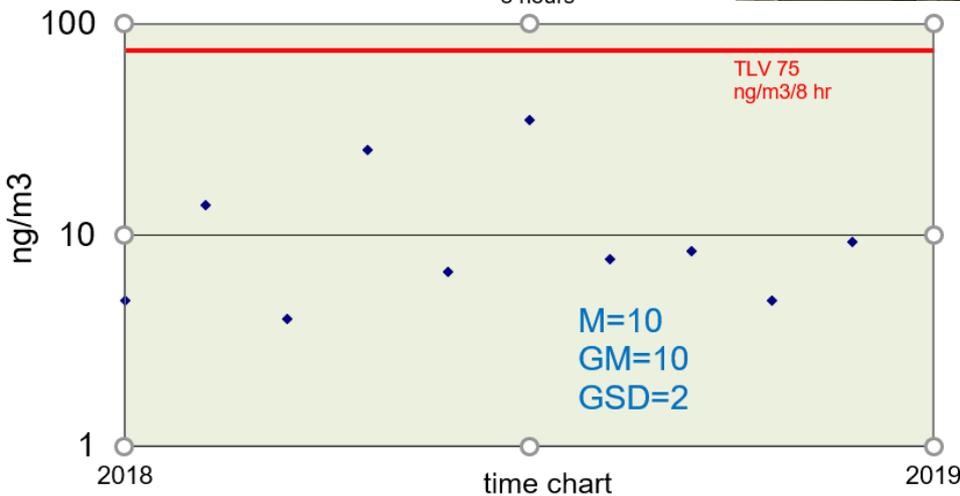
Which exposure patterns are typical for these exposure profiles?
(double containment, monitored ventilation)

C

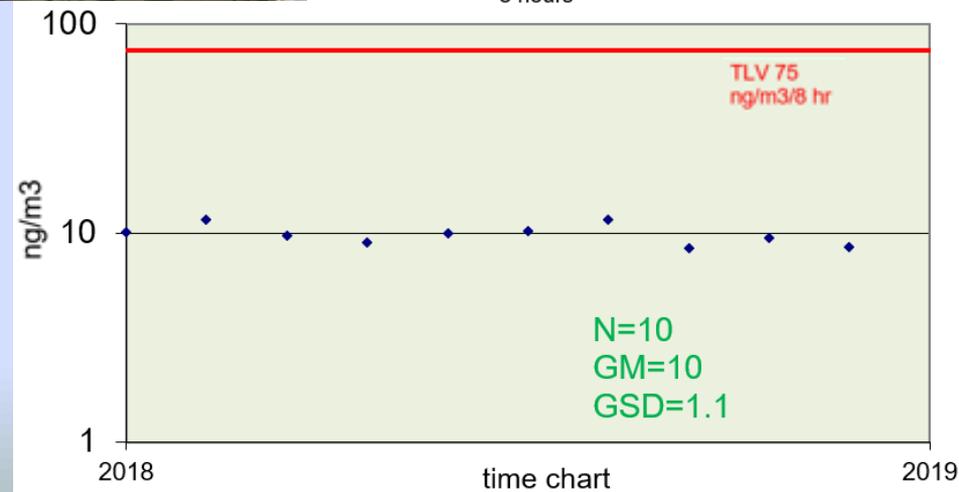


D

PAS TWA_{8 hours} in a SEG



PAS TWA_{8 hours} in a SEG



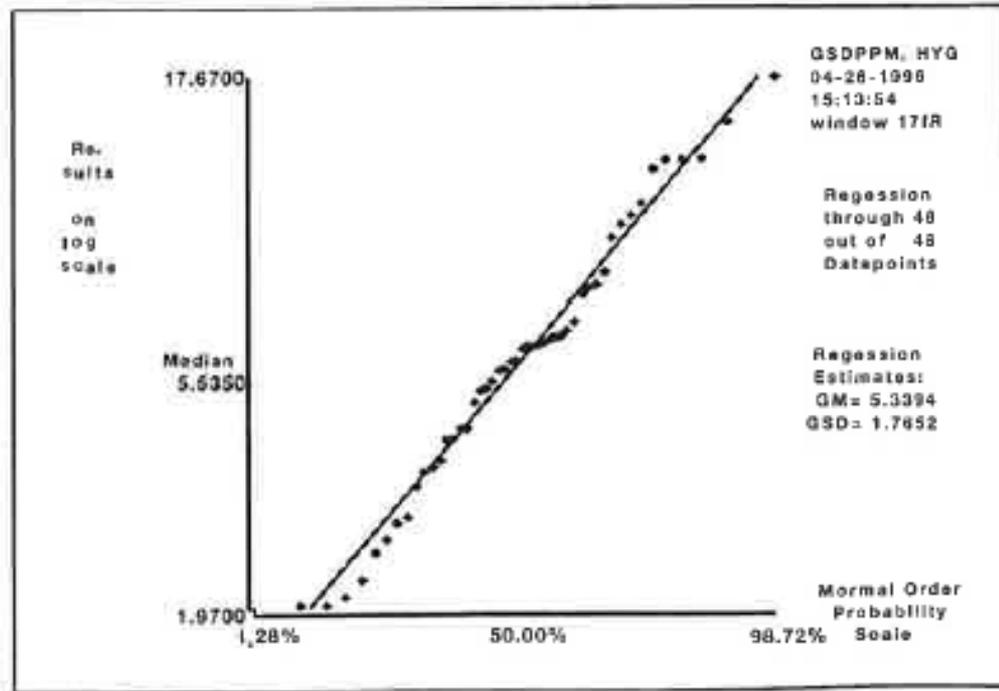
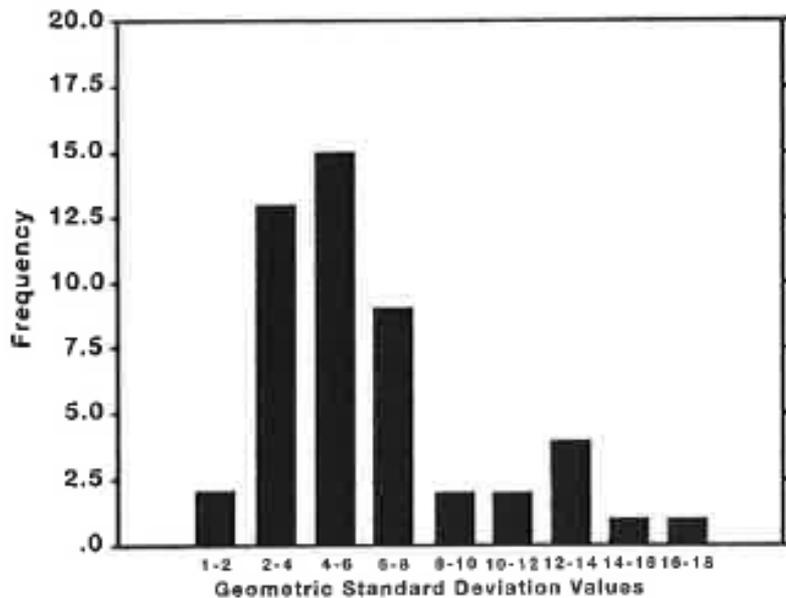
A library of specific GSDs

Theo Scheffers

NVvA Conference Session A

Wo 11 april 2018 11:00 Room RPS

GSD frequency and cumulative distribution



long-term GSD in chemical industry

Tijdschrift voor toegepaste Arbowetenschap 13 (2000) nr 4

T.M.L. Scheffers¹, J. Marquart², J.J. Twisk³

Typical Shift GSD's

GSD point estimate (BI 90%) exposure profile	GSD _{wp} within SEG premises/ companies	GSD _{bp} between premises/ companies	Reference
Gasses & vapours (range)	5.3 (1.4 ->14)		Scheffers, Marquart (2000)*
Solid	3.03	3.61	Tielemans table 7 (2008)**
Liquid	5.67	3.21	
Handling powders and granules	3.84	7.41	Schinkel Table 3 (2010)
Handling resulting in comminuting	3.09	4.54	
Handling low volatile substances	7.04	4.42	
Handling volatile substances	3.18	6.88	
GSD point estimate (range) Exposure profile	within worker GSD _w	Between & within worker (SEG) (b+w) GSD _{b+w}	reference
Vapours (range)	(1.2->5.6)	(1.2->8.4)	Kromhout (1993) Table 1 ***
Aerosols (range)	(1.3->8.2)	(1.4->17.6)	
Grain dust, inspirable BWSTAT P(ANOVA)=0.86	2.9	2.9	
Grain dust, inspirable endotoxin (BWSTAT) P(ANOVA)=0.83	3.1 -	4.3 5.7	Kromhout (1993) raw data ****

Default GSD for vapors/gasses: 5.4

* Long-term sampling, SEGs in chem. industry, goodness-of-fit, LoQ regression

** Reasonable 'Worst-case' sampling, LoQ/2

*** Poor quality data (Symansky, 2006) & analysis (GSD_b<1), LoQ/2

**** $GSD_B = \text{EXP}\{[\ln(GSD_{(B+W)})^2 - \ln(GSD_W)^2]^{1/2}\} = 2.5$



In conclusion

- **A GSD is a property of a SEG exposure profile**
- Valid small and large GSDs both exists
 - Long-term $TWA_{8 \text{ hours}}$ GSD's may have values up to 14
 - Preliminary test (5.5.2) not valid
 - specific, worst case scenario GSD will be smaller
 - If $GSD < 4$ Preliminary test (5.5.2) valid
- Check GSD against models en historical data

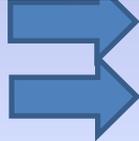


4.II Validation SEG

C. Models & history

Beoordeling basiskarakterisering

- Stoffenregister (5.1.2)
- Werkplek factoren (5.1.3)
 - Activiteiten (duur)
 - Inrichting
 - beheersmaatregelen
- SEG (5.2.1)



1. $Tl_{95\%,70\%} \leq OELV$
 2. $0.2 < C_i / OELV \leq 1$
- Model/database info ontbreekt !



Beoordeling § 5.1.5: niet volledig groen: # wat zeggen de modellen?

Laag	Blootstelling is ruim onder de grenswaarde <ul style="list-style-type: none"> • metingen niet nodig; • rapporteren + advies voor herbeoordeling
Onduidelijk	Onvoldoende informatie om beslissing te nemen <ul style="list-style-type: none"> • Opstellen van meetplan

Trexmo exposure model family

trexmo.chuv.ch/home/

Tier 1
Saved ES

Tier 2
Chemicals

All-in-one
Library

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

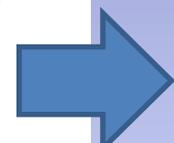
Federal Department of Economic Affairs FDEA
State Secretariat for Economic Affairs SECO
Labour Directorate

IST
Institute for Work and Health

Unil
UNIL | Université de Lausanne

scaht

CHUV

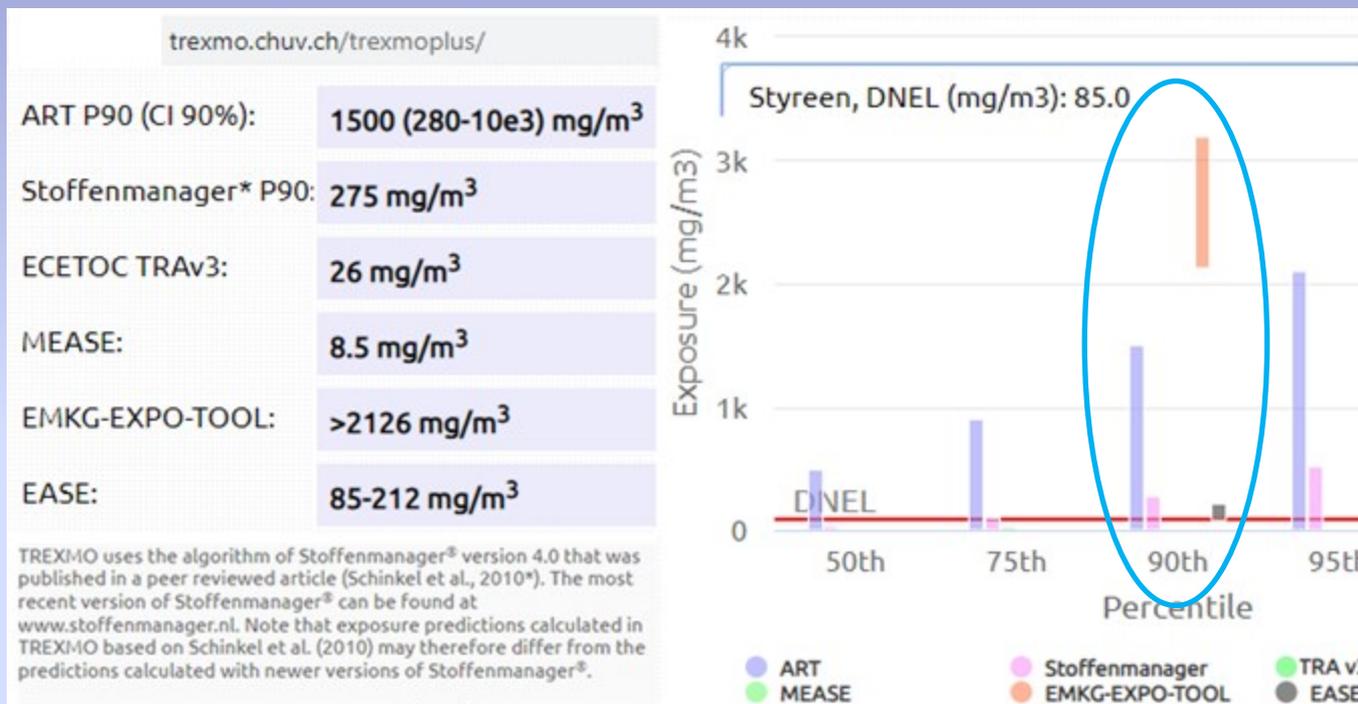


- ART
- MEASE
- Stoffenmanager
- EMKG-EXPO-TOOL
- ECETOC TRA v3
- EASE



<http://trexmo.chuv.ch>

5.1.4. blootstellingsschatting



De meeste ['I-SZW modellen'](#) staan in de Trexmo hub ('gebruikersinterface')
Ze geven extreem verschillende blootstellingen !!
Wordt aan de OELV van 85 mg/m³ voldaan?



4.II Validation SEG

C. history (databases/literature)

To be included (after 2021 NVvA conf.)



4.II Validation SEGs

D. Compare measurements with
models/history

Passen modellen en metingen bij elkaar?

MEASE 1.02.01

© 2009, 2010 EBRC Consulting GmbH

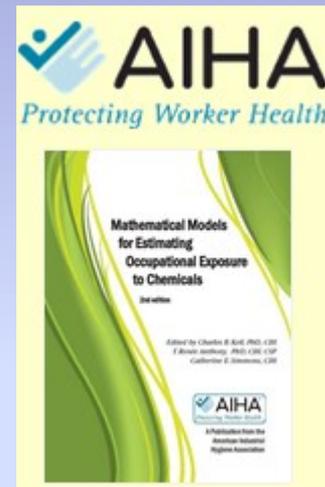
Exposure Assessment Tool

D. Vetter

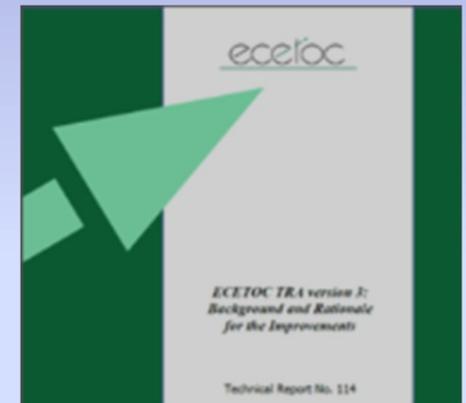
For Metals And Inorganic Substances

Hannover, Germany

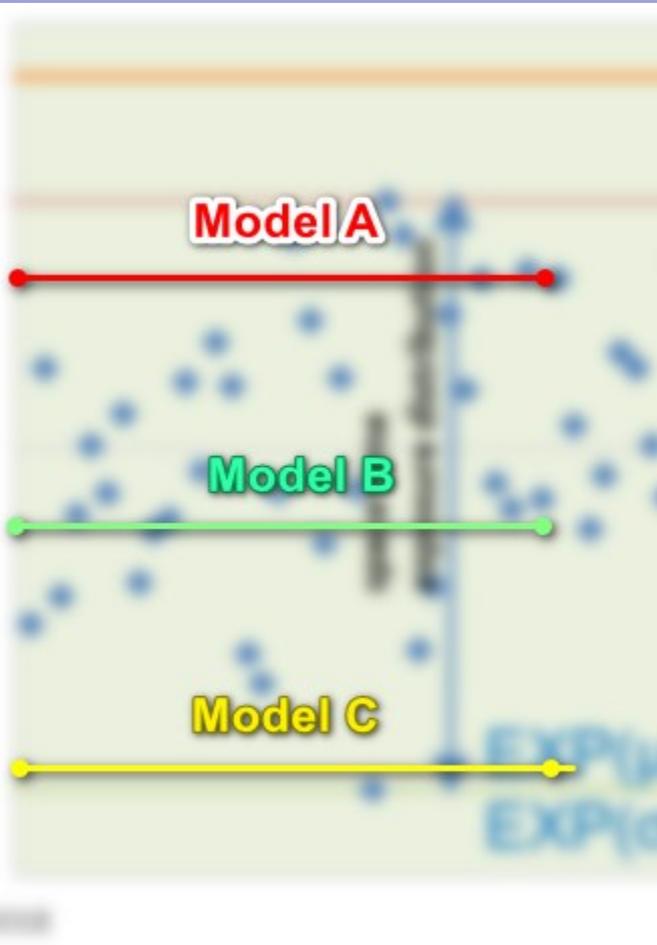
 **Stoffenmanager[®]7**



IH Mod



 **AIHA** *Protecting Worker Health*
Qualitative Exposure Assessment tool
Exposure Assessment Strategies Committee
The Checklist

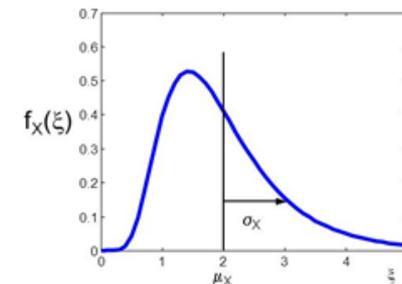


Vergelijk metingen en modellen (5.1.5)

Uitgangspunten

- Modellen en metingen zijn log-Normaal
- Vergelijk de spreiding (dispersie) en het niveau (locatie)
- surogaat 'populatie referentie' waarden afleidbaar uit sommige modellen
 - $EXP(\mu_x)$ en $EXP(\sigma_x)$
- Steekproef GM en GSD toetsen aan $EXP(\mu_x)$ en $EXP(\sigma_x)$ met Student-t test [Wikipedia](https://en.wikipedia.org/wiki/Student-t_test)/Excel

Lognormale verdeling



5.1.4. blootstellingsschatting



- 12,5 mg/m³
- 17,3 mg/m³
- GM= 14,7 mg/m³
- GSD=1.26

Not secure | trexmo.chuv.ch/trexmoplus/

ART P90 (CI 90%): **1500 (280-10e3) mg/m³**

Stoffenmanager* P90: **275 mg/m³**

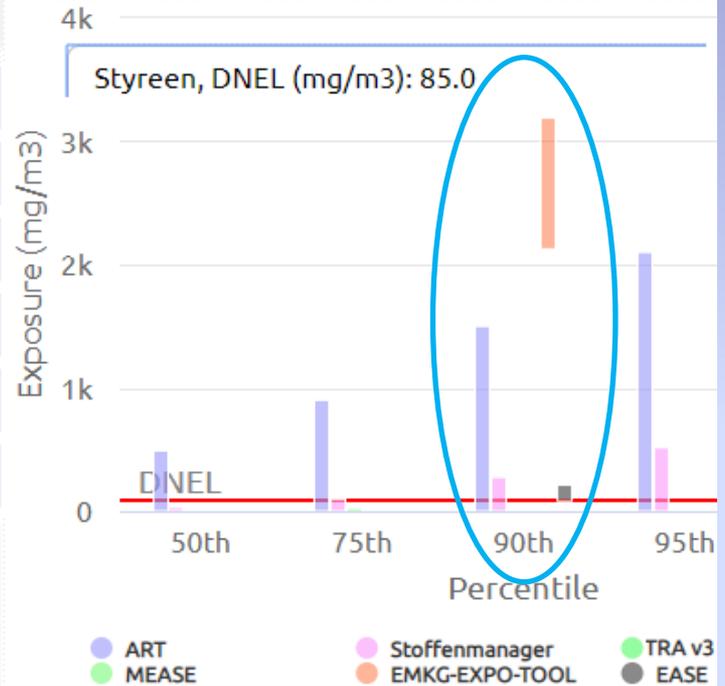
ECETOC TRAv3: **26 mg/m³**

MEASE: **8.5 mg/m³**

EMKG-EXPO-TOOL: **>2126 mg/m³**

EASE: **85-212 mg/m³**

TREXMO uses the algorithm of Stoffenmanager[®] version 4.0 that was published in a peer reviewed article (Schinkel et al., 2010*). The most recent version of Stoffenmanager[®] can be found at www.stoffenmanager.nl. Note that exposure predictions calculated in TREXMO based on Schinkel et al. (2010) may therefore differ from the predictions calculated with newer versions of Stoffenmanager[®].



$C_{90,70\%} = 33 \text{ mg/m}^3$
 $C_{90\%} = 20.2 \text{ mg/m}^3$

Model	EXP(μ)=50 th	EXP($\mu+1.28\sigma$)=90 th	EXP(σ)
StM [®]	31	275	5.4
ART	490	1500	2.4
EASE	?	>85	?
EMKG	?	>2126	?

5.1.4. GSD toetsen



- 12,5 mg/m³
- 17,3 mg/m³
- GM= 14.7 mg/m³
- **GSD=1.26**

Not secure | trexmo.chuv.ch/trexmoplus/

ART P90 (CI 90%): **1500 (280-10e3) mg/m³**

Stoffenmanager* P90: **275 mg/m³**

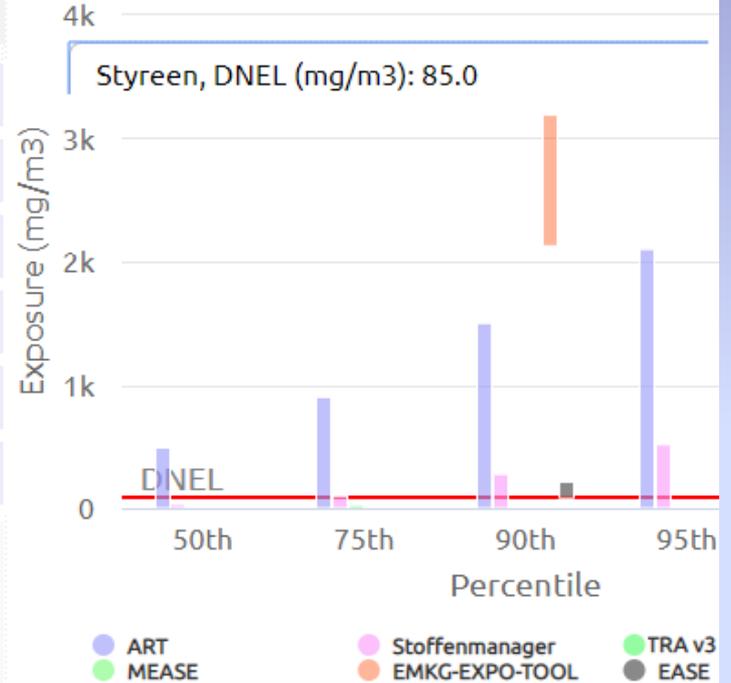
ECETOC TRAv3: **26 mg/m³**

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Model	EXP(μ)=50 th	EXP($\mu+1.28\sigma$)=90 th	EXP(σ)
StM [®]	31	275	5.4
ART	490	1500	2.4
EASE	?	>85	?
EMKG	?	>2126	?

Vergelijk de 2 metingen met ART

The screenshot shows the HYGINIST version 4.4.2 interface. The title bar reads "HYGINIST version 4.4.2 Comparison with the descriptive statistics of a second log-Normal distribution". The menu bar includes "File", "Statistics", and "Help". The "Compare" tab is active in the top navigation bar.

Descriptive statistics of the current data C:\Users\TS_com\zakelijk\projecten\klanten\14_NvVA_689_training\dropbox\Dropbox\Training_NENC

2 styreen metingen

Sample size M = 2
GM maximum likelihood = 14.7054 mg/m3
GSD = 1.2583

Type of reference data?
 Sample data
 Population

Choose:
Sample data: if the known reference sample size Mref, variability GSDref and location Gmref
Population: if the known reference population variability EXP(sigma)ref and location EXP(mu)ref

Population reference values

ART schatting

Reference population location EXP(mu) = 490 mg/m3
Reference population dispersion EXP(sigma) = 2.4

The probability that the sample origins from a population with the above mentioned descriptive statistics

The geom. standard deviation: two sided probability A(GSD=EXP(sigma)) = 41.4099 %
The geometric mean: two sided probability A(GM=EXP(mu)) = 2.9482 %

De metingen en ART verschillen.

De gemeten mediane blootstelling (GM) is (significant) 9 * lager dan ART EXP(μ)

Vergelijk de 2 metingen met StM[®]



HYGINIST version 4.4.2 Comparison with the descriptive statistics of a second log-Normal distribution

File Statistics Help

Start Raw data Limits Descriptive statistics Compliance Mean UCL Compare

Descriptive statistics of the current data **Styreen_voor interventie-Koen.hyg** Measured in: mg/m³

2 styreen metingen

Sample size M= 2 Sampling duration 8 hours

GM maximum likelihood= 14.7054 mg/m³

GSD= 1.2583

Type of reference data?

Sample data

Population

Choose:

Sample data: if the known reference sample size Mref, variability GSDref and location Gmref

Population: if the known reference population variability EXP(sigma)ref and location EXP(mu)ref

Population reference values

StM[®] schatting

Reference population location EXP(mu) = 31 mg/m³

Reference population dispersion EXP(sigma) = 5.4

The probability that the sample origins from a population with the above mentioned descriptive statistics

The geom. standard deviation: two sided probability A(GSD=EXP(sigma)) = 21.6774 %

The geometric mean: two sided probability A(GM=EXP(mu)) = 13.6573 %

De metingen en StM[®] verschillen in niveau en spreiding, maar niet significant.
Deze toetsing is (nog) niet mogelijk met BW-Stat



Application of prior GSD knowledge

- I. Preliminary test (5.5.2)
- II. Validation of SEG (5.4)
- III. Optimize sample size (5.3 & 7)

III. Optimize sample size

to test $C_{95\%,70\%} \leq OELV$ and
reassessment (5.3 & 7)

Sample size for statistical test 5.5.3

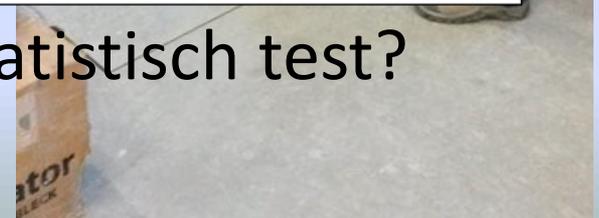
1. Using U_R and U_T of table F.1 (EN 689:2019)
or
2. [HYGINIST](#) Wilks methode

Ochtend Voorbeeld 4

- Metingen styreen
- Twee metingen
 - 12,5 mg/m³
 - 17,3 mg/m³
- $GW_{TGG-8hr}: 85 \text{ mg/m}^3$
- $C/GW \geq 0.2 \Rightarrow$
- Statistical test $N \geq 6$
- Hoeveel extra metingen voor de statistisch test?



Alle resultaten: $\leq 0,10$ (10%) GW voor 3 metingen $\leq 0,15$ (15%) GW voor 4 metingen $\leq 0,20$ (20%) GW voor 5 metingen	Compliance 5.5.2 a) 1-3
1 resultaat > GW	Non-compliance 5.5.2 b)
Alle resultaten < GW, maar ≥ 1 is: $> 0,10$ (10%) GW (voor 3 metingen) of $> 0,15$ (15%) GW (voor 4 metingen) of $> 0,20$ (20%) GW (voor 5 metingen)	Geen beslissing 5.5.2 c) / conclusie
Aanvullende metingen (tot minimaal 6) + statistische toets: hoogstens 5% grenswaarde overschrijding met 70% zekerheid, of 5% grenswaarde overschrijding met tenminste 70% zekerheid	



Sample size using U_R and U_T (Annex F table F.1 extended to $N=2$)

$$U_R \geq U_T$$

Number N of measurements	Limiting value of U_T for $TI_{95\%,70\%}$	Limiting value of U_T for $TI_{95\%,95\%}$
1		
2	4.21677	
3	2.80912	7.655
4	2.45308	5.145
5	2.28592	4.202
6	2.18677	3.707
7	2.12007	3.399
8	2.072	3.188
9	2.035	3.031
10	2.005	2.911
11	1.981	2.815
12	1.961	2.736
13	1.944	2.67
14	1.929	2.614
15	1.917	2.566
16	1.905	2.523
17	1.895	2.486
18	1.886	2.453
19	1.878	2.423
20	1.870	2.396

	mg/m3	ln()
GW-TGG	85	4.442651
GM	14.7054	2.688215
GSD	1.2583	0.229762
Ur=		7.635899

$$U_R = \frac{\ln(\text{OELV}) - \ln(\text{GM})}{\ln(\text{GSD})}$$



$$U_R \geq U_T$$

In compliance! So any additional ≥ 4 samples is sufficient to perform the statistical test 5.5.3!

U_T values for $N=2 \rightarrow 5$ from BWSTAT

Meer metingen nodig ? (§5.1.5)

Vergelijk metingen GM & GSD met de modellen EXP(μ) & EXP(σ)

- ART: afwijkend, **herbeoordeel basis karakterisering**
- StM[®] niet significant afwijkend met de metingen:

1. C_i òf $Ti_{95\%,ML} > OELV \Rightarrow$ rapporteer -> RMM -> 5.1
2. $0.1 < C_i / OELV \leq 1$ òf $Ti_{95\%,ML} < OELV \leq Ti_{95\%,70\%} \Rightarrow$ **5.2 meer meten**
3. $C_i / GW \leq 0.1$ èn $Ti_{95\%,70\%} \leq OELV \Rightarrow$ doeltreffend \Rightarrow 6 rapporteer



Sample size using HYGINIST/Wilks more conservative for small samples

The screenshot shows the HYGINIST version 4.4.2 interface. The 'Compliance' tab is active, displaying the following data:

Descriptive statistics of the current data

Name	C:\Users\TS_com\zakelij\projecten\klanten\14_NvvA_689	
Sample size M=	2 samples of 8 hours	
Degrees of Freedom df=	1	
GM maximum likelihood=	14.7054	mg/m3
GSD=	1.2583	

Statistical test: Wilks, Unbiased (1947)

Occupational Exposure Limit Value OELV=	85 mg/m3 \ 8 hours	
Percent exceedance A(C>OELV) =	5.0631	%
The 95 % upper tolerance limit	86.9344	mg/m3

**HYGINIST/Wilks(1941)
Non-Compliance**

The unbiased estimate of the non-compliance probability A is the hallmark of this quality control method. Algorithms from Wilks (1947) and Proschan (1953). A Lognormal goodness-of-fit should be at least probable. Referring to Leidel (1977 p69), engineering controls should be installed if A>5%.

Optimize sample size for long term compliance control

Non-compliance on average, for df=	3	
Corresponding unbiased compliance probability A(C>OELV)>=	1.1059	%
Corresponding minimum sample size Mopt=	4	

Given GM, GSD and OELV, the minimum sample size Mmin is calculated for which the non-compliance using the method of Wilks (Proschan Am. Stat. Assoc. J. 48 (1953) 550-564). Compliance on average, if sample size increases to Mopt. See manual chapter 7.2.

Buttons at the bottom: IHStat/Leidel(1977) | **HYGINIST/Wilks (1941)** | EN 689(2018)/ Tuggle(1982)

Oefening

Met hoeveel metingen is Example F.1 wèl in compliance ?

$$U_R \geq U_T$$

voor N=10 is $U_R \geq U_T$
Compliance!

Number N of measurements	Limiting value of U_T for $C_{95\%,70\%}$
1	
2	4.21677
3	2.80912
4	2.45308
5	2.28592
6	2.12007
7	2.072
8	2.035
9	2.005
10	1.981
11	1.961
12	1.944
13	1.929
14	1.917
15	1.905
16	1.895
17	1.886
18	1.878
19	1.870
20	

EXAMPLE F.1 page 44

A series of six exposure measurements following a log-normal distribution is used to test compliance with an OELV of 10 mg/m³.

Result in mg/m ³	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 mg/m³

GSD = 2,37

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

$U_R = 2,009$

Non compliance for N=6

Steekproefomvang bepalen nog niet in BWStat

Aantal metingen N voor de statistische test 5.5.3

Aanpak

- A. Meet 6+ sequentieel, at random in de tijd tot $C_{95,70\%} \leq OELV$
- B. Bepaal N met GM, GSD, OELV en
 - HYGINIST/Wilks,
 - U_R en de tabel F.1 met U_T waarden



Bepaal GM en GSD uit 'Estimation of Exposure' 5.1.4

- Eerdere metingen
- modellen
- database, bibliotheek, literatuur, read-across

5.1.4. Model based sample size N



12,5 mg/m³
 17,3 mg/m³
 GM= 14,7 mg/m³
 GSD=1.28

C_{90,70%} = 33 mg/m³
 C_{90%} = 20.2 mg/m³

Not secure | trexmo.chuv.ch/trexmoplus/

ART P90 (CI 90%):	1500 (280-10e3) mg/m ³
Stoffenmanager* P90:	275 mg/m ³
ECETOC TRAv3:	26 mg/m ³
MEASE:	8.5 mg/m ³
EMKG-EXPO-TOOL:	>2126 mg/m ³
EASE:	85-212 mg/m ³

TREXMO uses the algorithm of Stoffenmanager® version 4.0 that was published in a peer reviewed article (Schinkel et al., 2010*). The most recent version of Stoffenmanager® can be found at www.stoffenmanager.nl. Note that exposure predictions calculated in TREXMO based on Schinkel et al. (2010) may therefore differ from the predictions calculated with newer versions of Stoffenmanager®.

Number N of measurements	Limiting value of U _T for C _{95%,70%}
1	
2	4.21677
3	2.80912
4	2.45308
5	2.28592
6	2.18677
7	2.12007
8	2.072
9	2.035
10	2.005
11	1.981
12	1.961
13	1.944
14	1.929
15	1.917
16	1.905
17	1.895
18	1.886
19	1.878
20	1.870



Model	GM=50 th	C _{90%} = GM * GSD ^{1.28}	GSD	U _R
StM [®]	31	275	5.4	0.82
ART	490	1500	2.4	-2.0

U_R < U_T
 Non compliance for every sample size!

Reference GSD based sample size N



12,5 mg/m³

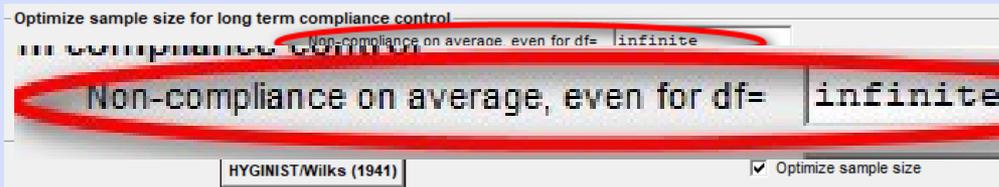
17,3 mg/m³

GM= 14,7 mg/m³

~~GSD=1.28~~

Default for vapors/ gasses
GSD=5.4

Number N of measurements	Limiting value of U _T for C _{95%,70%}
1	
2	4.21677
3	2.80912
4	2.45308
5	2.28592
6	2.18677
7	2.12007
8	2.072
9	2.035
10	2.005
11	1.981
12	1.961
13	1.944
14	1.929
15	1.917
16	1.905
17	1.895
18	1.886
19	1.878
20	1.870



GM	GSD	U _R
14.7	5.4	1.04

Non-compliance for every sample size!

Kloppen de 2 meetuitkomsten?



EN 689 5.2.2 Specifying the measurement procedure

Aim : Representative measurements for the SEG exposure profile.

Requirement: All possible conditions present and expected throughout time

- Using PAS
- Sampling duration
 - for OELV-8 h:
 - Constant exposure during work shift: ≥ 2 hours -> reference period OELV
 - Non-constant workplace factors: ≥ 2 hours -> work shift duration
 - Exposure duration < 2 hours: Sampling duration = Exposure duration
 - for OELV15min(-> 8h): sampling duration = reference period
- Number of samples
 - in accordance with 5.5.2 and 5.5.3
 - Different workers and locations, if relevant
 - different times (shifts?)



Verdieping & Aanvullingen

1. Maatschappelijk draagvlak
2. NL definities en begrippen

Efficiency/betrouwbaarheid vergroten:

3. Inzoomen op het hoogste risico.
4. EN689 Priors
5. Aanvullende Priors

Geschikte (online) instrumenten

Bruikbaarheid buiten (EU) Arboregelingen

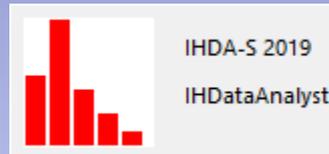


Application of prior GSD knowledge

- I. Preliminary test (5.5.2)
- II. Validation of results and SEG (5.4)
- III. Optimize sample size (5.3 & 7)
- IV. Bayesian statistical tools**

Efficiency/betrouwbaarheid vergroten ?

5. Bayesiaanse priors



Bayesiaanse ob/subjective priors moeten worden geloofd

5. $1.05 < \text{GSD} < 4$
6. $\text{GM} < 10 * \text{OELV}$
7. Metingen \Leftrightarrow Model berekening

Parameter Space Boundaries

Exposure Category Cutoffs | Parameter Space Boundaries

OEL = 5 ppm

Default

minimum GM = 0.00102238 0.00102238

maximum GM = 25 5 x OEL

minimum GSD = 1.05 1.05

maximum GSD = 4 4.0

Save GSD's as Defaults | Reload Default GSDs

Settings in IHDA

What does Bayes add to exposure assessment?

Bayesian Versus Frequentist Estimation for Structural Equation Models in Small Sample Contexts: A Systematic Review

Sanne C. Smid, Daniel McNeish, Milica Miočević & Rens van de Schoot

To cite this article: Sanne C. Smid, Daniel McNeish, Milica Miočević & Rens van de Schoot (2020) Bayesian Versus Frequentist Estimation for Structural Equation Models in Small Sample Contexts: A Systematic Review, *Structural Equation Modeling: A Multidisciplinary Journal*, 27:1, 131-161, DOI: [10.1080/10705511.2019.1577140](https://doi.org/10.1080/10705511.2019.1577140)

To link to this article: <https://doi.org/10.1080/10705511.2019.1577140>

Bayes en beoordelen blootstelling

- beschikbaar als freeware
- Tools zijn schimmig over priors & methode
- Recente studie:
 - winst voor kleine steekproeven beperkt/negatief
 - Modieus, te makkelijk beschikbaar
- Verdient verdere kritisch onderzoek
- Gebruik op eigen professionele verantwoordelijkheid

Question on Bayesian tools

- What priors are included in addition to the regular ones, like (log)normal shape, regression LoD ?
- How valid are these priors ?



Aanbeveling

NVvA (via EU platform) :

Validatie van aanvullende EN689 priors (niet alleen Bayesiaans) die de efficiency vergroten zonder de betrouwbaarheid geweld aan te doen

Naar een volgende standaard (202#) vanuit de EU AH verenigingen

Samenvatting

1. Maatschappelijk draagvlak
2. NL definities en begrippen

Efficiency/betrouwbaarheid vergroten:

3. Inzoomen op het hoogste risico.
4. EN689 priors
5. Aanvullende Priors

6. geschikte (online) instrumenten
7. Bruikbaarheid buiten (EU) Arboregelingen



Meeneem boodschappen

- Gebruik en promoot deze standaard, maar niet kritiekloos!
- preliminary test (5.5.2) met $\text{Exp}(\sigma)$ onbekend, alleen voor naleving/handhaving (indien erkend door I-SZW)
- [BWSTAT V3](#) sluit het best aan op EN689
- HYGINIST beoordeelt de vorm incl. LoD's, optimaliseert de steekproefomvang



Meeneem boodschappen (2)

NVVA (/EU platform) ontwikkel punten

- ‘Olifantenpaadje’: <3 metingen beoordeling
- Database GSD
- Bayes mag geen trukkendoos zijn: Priors onderbouwen (Univ)