Significant between worker (B&W) differences

BOHS 2013 Conference Manchester
24 April 2013 Session 8b
17:05 – 17:35
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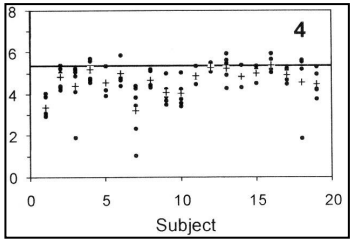
British Occupational Hygiene Society
Working for a healthier workplace

Nederlandse Vereniging voor Arbeidshygiëne

This presentation



1. The BOHS-NVvA Guidance
2. B&W differences: real or artifacts?
3. Some examples
4. Consequences of the BW approach
5. Recommendations: how to check on BW differences
6. Further improve the Guidance

The BOHS-NVvA Guidance (2011)

Testing Compliance with

Occupational Exposure Limits

for Airborne Substances

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

September
2011

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Arbeidshygiëne
Postbus 1762,
5602 BT Eindhoven
The Netherlands
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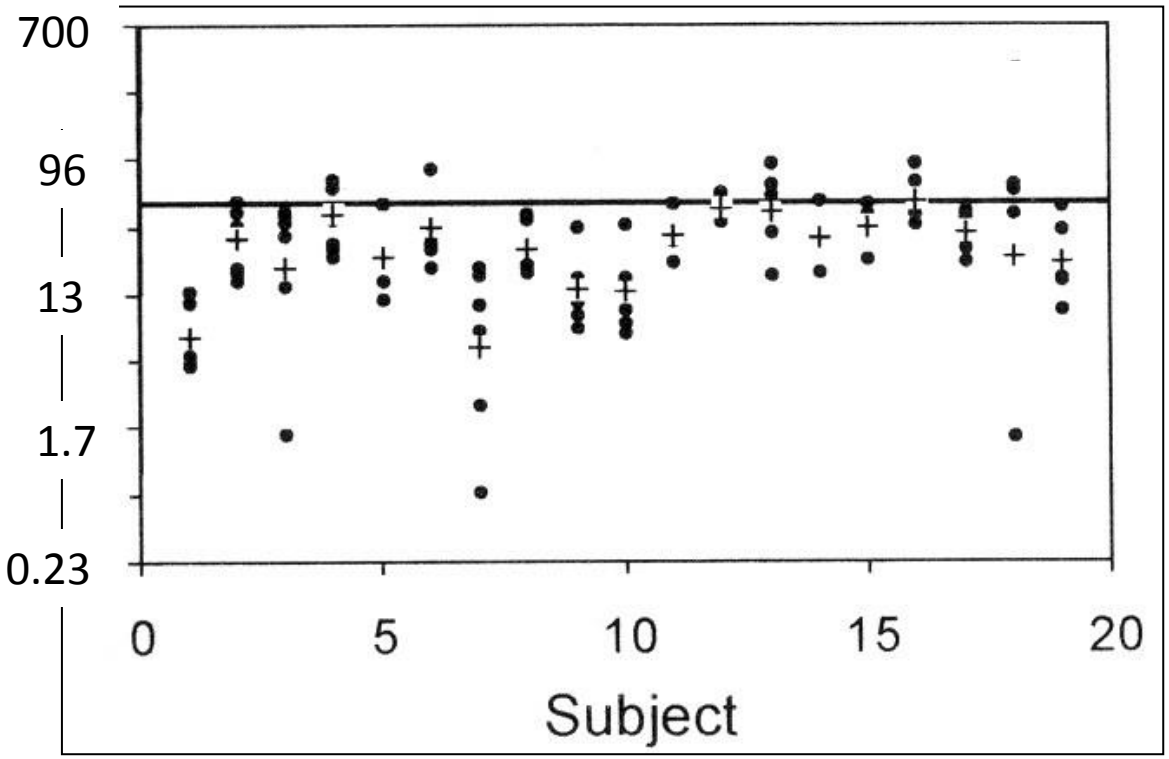
"This document aims to give guidance to occupational hygienists and others on measurement strategies …. for determining compliance with occupational exposure limits".

Demonstration of BW_Statv1. Thursday 25/4 /2013
Syndicate room running Sessions 'C' on the second floor

Kromhout 2007 BOSH presentation stressing the importance of including the individual compliance in a compliance testing guidance

B&W differences in location GM: Real or artifacts?



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

Important addition :
Introduction of individual compliance testing

If the between-worker variation within a SEG makes an important contribution to the total variation, it is necessary to test individual compliance.

Small or large exposure variability in SEGs?

Small:

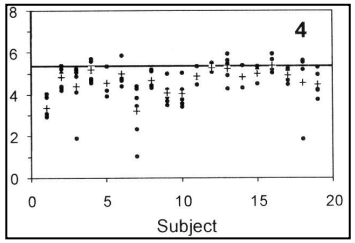
- Old days industrial use,
- high-tech clean rooms,
- Well defined tasks based Operational Conditions (as in REACH CSR),
- as an artifact in:
  - 2-decades analytical methods (like gravimetric dust sampling)
  - simple methods to handle undetectables (LoQ/2).

Large:

- Professional use & non dedicated industrial use,
- Dedicated industrial use since the 70^{s}
  - Single task based jobs disappeared, multi-craft jobs in industry
  - Less variability dimming background levels

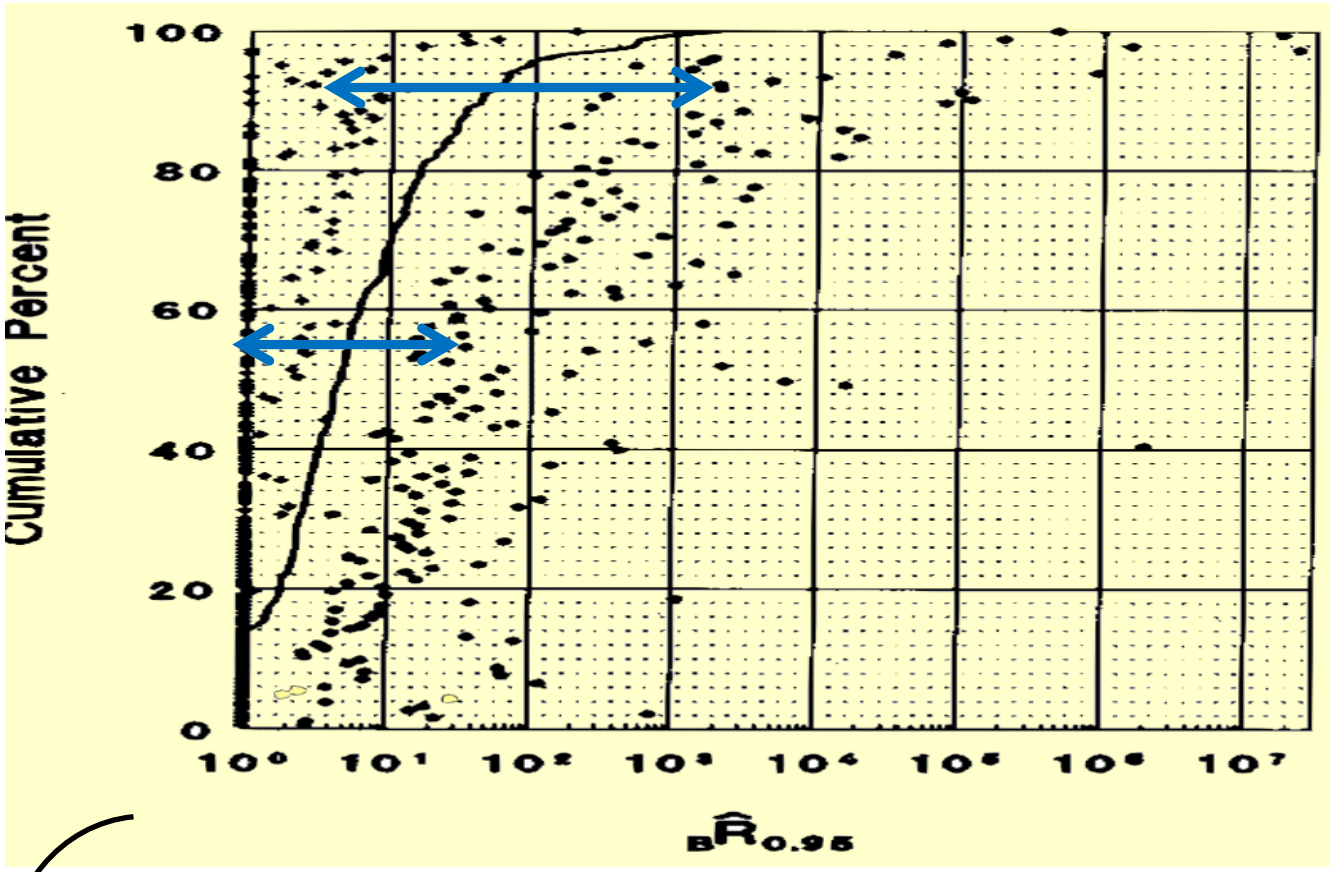
  So: alltough levels decreased, exposure variability may have increased!

Why significant differences between workers are found in a SEG?



- Personal factors:
  - experience, physical, behaviour
- Operational condition artifacts:
  - Several jobs and tasks in a SEG (the old Homogeneous EG concept)
- Biased exposure assessment :
  - short sampling campaigns: job rotation not included
  - Small # per worker -> different tasks profiles per SEG worker.
    "spraying or laminating in boat manufacture"
  - Bad LoD handling: Lower GSD's for workers near the LoD,
  - Bad statisticals methods

Between worker $_{B}R_{0.95}$ = ratio of 95% upper & lower **mean** (BW)
Rappaport/Kromhout (1993)



- 85% SEGs $_{B}R_{0.95}$> 2: large BW variability
- With confidence intervals ≤ 30% SEG significant BW differences
- Short-term sampling campaigns may cause non-existing BW differences
- 5% significant BW differences due to chance

[These studies provided limited/no evidence that BW is important]

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NVvA/BOHS guidance:

Individual differences within a SEG may exists, but this must by checked.

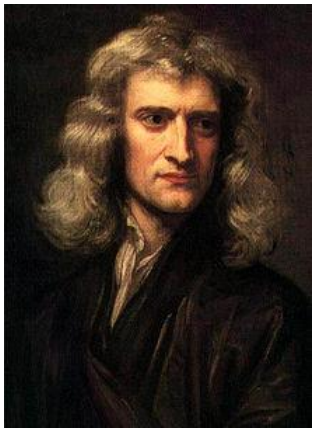
NVvA-BOHS Guidance BW ad hoc criterion

- If the between-worker variance exceeds 20% of the total variance, then perform the individual compliance test.
- **“No additional value for P(ANOVA)<5%”**

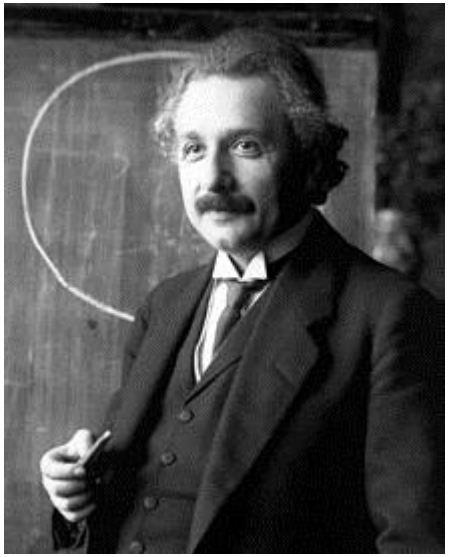
Supported by simulation data (?)

Your gravitation approach has no additional value!

$$F = G\frac{m_1 m_2}{r^2}$$



$$G_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

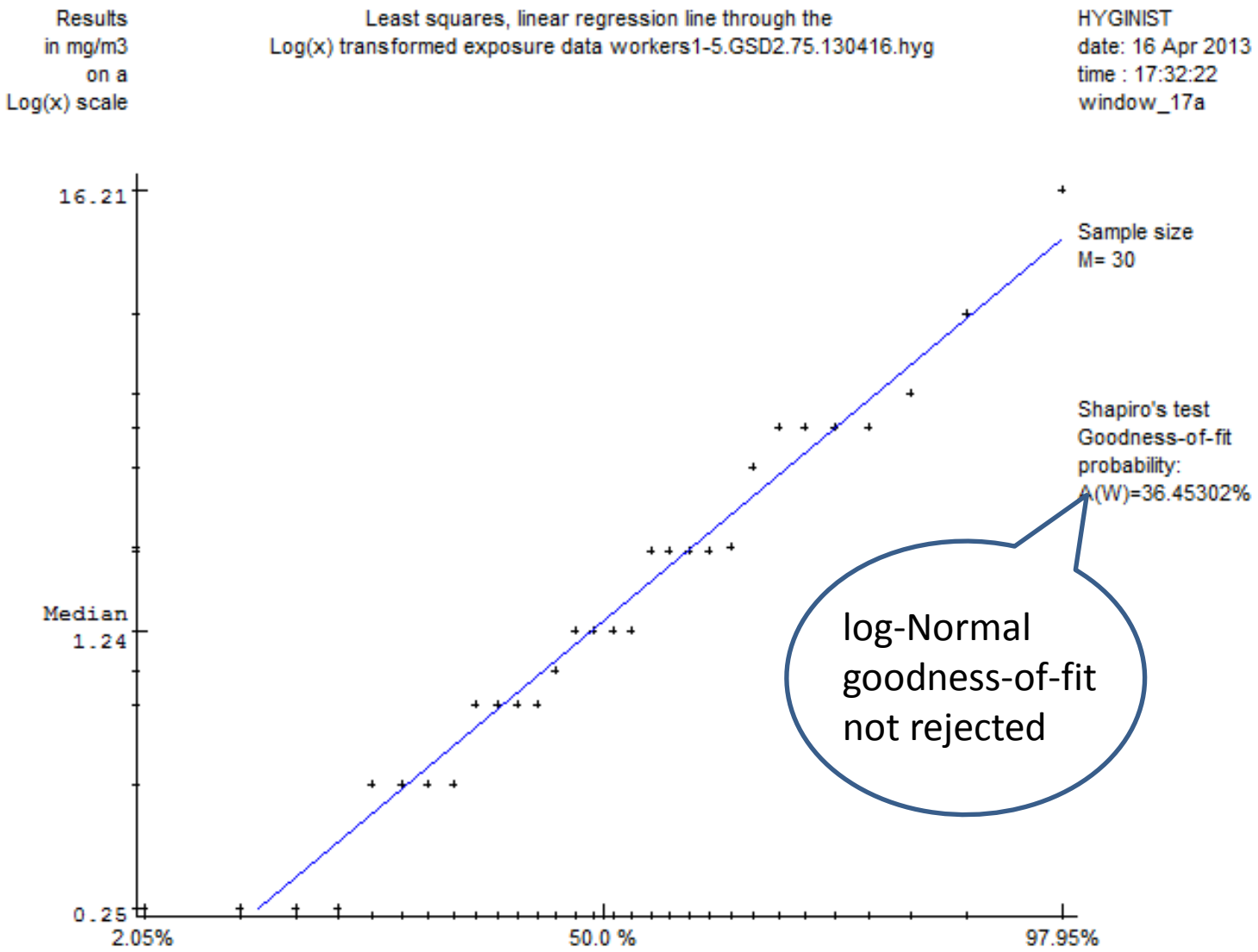


Example A: 5 workers, 1 outlier, OEL=10

No real data, but expected values for sample size 6

	worker 1	worker 2	worker 3	worker 4	worker 5
sample 1	4.05	4.05	4.05	4.05	16.21
sample 2	1.98	1.98	1.98	1.98	7.91
sample 3	1.24	1.24	1.24	1.24	4.95
sample 4	0.81	0.81	0.81	0.81	3.23
sample 5	0.51	0.51	0.51	0.51	2.02
sample 6	**0.25**	**0.25**	**0.25**	**0.25**	0.99
n	6	6	6	6	6
GM	1	1	1	1	4
GSD	2.75	2.75	2.75	2.75	2.75

Log-Normal probability plot 5 workers



BW using the NVvA-BOSH guidance: outlier

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

Input			
Unit	mg/m³	Substance name	inhalable dust
Occupational Exposure Limit (OEL)	10.00	total number of workers	5
10% Occupational Exposure Limit (10%OEL)	1.00	total number of measurement da	6
Lower Limit Of Quantification (LoQ)	0.25	total number of measurements	30
Results			
Countings			
Number of samples <10%OEL	13	Number of samples <LoQ	4
Number of samples =>10%OEL and <=100%OEL	16	Treatment of measurements <LoQ (Section 3.7):	
Number of samples >100%OEL	1	Stage 1 compliance testing not possible as LoQ>0,1 OEL. Use regression methods on data >LoQ in the lognormal probability plot to estimate GM, GSD and group compliance	
Compliance testing			

Stage 0: Screening test (Section 3.3)			
Are any of the samples =>0,1 OEL?	Yes, see next line		
…les >1,0 OEL?	Yes, see stage 1 group compliance test		
…: Group compliance test (Section 3.4)			
UTL95%,70%	9.44	<	OEL 10 mg/m³
…up comply with the OEL?	Use regression methods to treat the undetectables correctly.		
Stage 2: Appl… …OVA and if necessary Stage 3 (Section 3.5)			
P(ANO…	0.08	>	p criterium 0,05
P(ANOVA)	No important differences between the workers. Individual compliance test not needed.		
P(B&W)	18.21%	<	ad-hoc criterium 20%
P(B&W)	No important differences between the workers. Individual compliance test not needed.		

No important differences between the workers.
Individual compliance test not needed.

2 sample Student t-test: outlier

```
HYGINIST version 4.3.1
Comparing the descriptive statistics of two log-Normal estimators GM and GSD. T

Descriptive statistics of worker 5 (GM=4 GSD= 2.75)
Sample size M=                                                    6
GM maximum likelihood=                                            4.0006
GSD=                                                              2.69944

Descriptive statistics of worker2 1 to 4 (GM=1 GSD= 2.75)
Reference sample size Mref =                                      24
Reference sample location GMref =                                 1.0044
Reference sample dispersion GSDref =                              2.5145

The probability that the two samples origin from the same population distribution
The geom. standard deviations: two sided probability A(GSD1-4=GSD5) =          71.70654
The geometric means: two sided probability A(GM1-4=GM5) =                      1.75165%
```

Example B: GSD increases

5 workers, 6 expected values, GSD^2

	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**
n	6	6	6	6	6
GM	1	1	1	1	1
GSD	1.12	1.2544	1.573519	2.475963	6.130394

BW according to the NVvA-BOSH guidance

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)			
%,70%	4.73	<	OEL 10 mg/m³
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: App… NOVA and if necessary Stage 3 (Section 3.5)			
P(A…A)	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.		

No important differences between the workers.
Individual compliance test not needed.

BW test not sensitive for differences in GSD

BW GSD differences

- With GM equal, non-compliance probability increases when GSD increases
- GSD differences not identified by B&W & single factor ANOVA

	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

Serious consequences of the BW approach

- n samples per worker in stead of n samples per SEG
- chasing the “black sheep” in the SEG with statistics

- Interests other than sound science

Recommendations (1)

Careful statistical evaluation on between worker differences

1. Check: Do sample data violate one-way ANOVA assumptions?
   http://www.basic.northwestern.edu/statguidefiles/oneway_anova_ass_viol.html#Unequal%20population%20variances
   - Group & individual log-normal goodness-of-fit: probability plots & omnibus tests (Shapiro & Wilk)
   - Bartlett & Levine: GSDs differences
   - Two sample t-test: individual outlier (GM &/or GSD)

Recommendations (2)

2. Unbiased exposure assessment strategy (EAS):
   - Is all **job** rotation included?
   - Are **tasks** sampled over the workers in the SEG?
   - Is a short or long-term sampling campaign performed?
   - Is random, stratified or worst-case sampling performed?
   - Are there sampling method limitations ?
3. With no EAS bias and no ANOVA assumptions violation, use P(ANOVA) or other validated tests to detect B&W differences.
4. Use robust statistical methods to test group & individual compliance

- Beware for a statistical witch-hunt on high exposed
- Differentiate between Task (REACH, RMM check) & SEG (Worker) based exposure assessment strategies
- Work to be done for NVvA-BOSH guidance v2