REALITY OF PPE PERFORMANCE

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OBJECT OF PERSONAL PROTECTIVE EQUIPMENT?

To protect workers in their workplaces

INFORMATION TO BE SUPPLIED BY THE MANUFACTURER

89/686/EEC – Annex ll para 1.4(d)

"The classes of protection appropriate to different levels of risk and the corresponding limits of use"

INFORMATION TO BE SUPLIED BY THE MANUFACTURER

As PPE are intended to be used in the workplace, manufacturers should provide information relevant to the protection likely to be obtained in the workplace!

WORKPLACE PERFORMANCE OF PPE

This presentation will examine the real-world performance of Respiratory Protective Equipment (RPE) and Personal Hearing Protective Devices (PHPD)

WORKPLACE PERFORMANCE OF RPE

WORKPLACE PERFORMANCE OF RPE

Information on the Workplace Protection Factors (WPF) achieved by RPE when worn by real workers in real workplaces has been published since the early 1980s

WPF FOR FULL MASKS WITH P3 FILTERS

Device	NPF	Lab PF	WPF*
A	1,000	>10,000	27
B	1,000	>10,000	78
C	1,000	>10,000	11

**** Geometric 95th%ile***

Tannahill (1991)

WPF FOR EN147 FULL MASKS WITH P3 FILTERS

Device	NPF	Lab PF	WPF
R1	2,000	>100,000	41
R2	2,000	>100,000	124
R3	2,000	>100,000	128
R4	2,000	>10,000	15

Howie et al (1996)

LAB PF v NPF v WPF

Lab PF >5-50xNPF > 20-50xWPF

WPF FOR OTHER DEVICES

Numerous other WPF studies on RPE have also demonstrate that workplace performance is generally much lower than in laboratory tests

EFFECT OF WPF DATA IN THE UK

Until the 1990s RPE had been selected in the UK on the assumption that the standard leakage tests adequately indicated likely workplace performance

EFFECT OF WPF DATA IN THE UK

Given the WPF data it was agreed that such data would be analysed with the intention of setting Assigned Protection Factors (APF) that would thereafter be the basis of RPE selection

ASSIGNED PROTECTION FACTORS

Where possible APF were based on actual WPF, in some cases where no WPF were available the AFP were set by analogy, eg fresh air hose devices were set the same APF as -ve pressure filter devices

ASSIGNED PROTECTION FACTORS

The APF, and other relevant guidance, were published in BS4275 in 1996.

APF – FILTER DEVICES

Filter	Facepiece	APF
P1	all	4
P2	½ mask, Full-face	10
P3 Gas, GasXP3	½ mask Full-face	20
P3	Full-face, hood, blouse	40

APF – BREATHING APPARATUS

Device	Facepiece	APF
Light duty, air hose	½	10
Light duty, airline	½	20
Light duty, air hose, airline or self-contained -ve demand	Full-mask, hood as relevant	40
Light duty, air hose, airline or self-contained -ve demand	Mouthpiece, semi-blouse as relevant	100
Continuous flow airline	Full suit	200
Airline	Mouthpiece	1000
Airline or self-contained +ve demand	Mouthpiece or Full-mask	2000

COMMENTS

Some of the WPF data used were based on inadequate in-mask sampling techniques that were likely to underestimate the in-mask contaminant levels and therefore overestimate the WPF

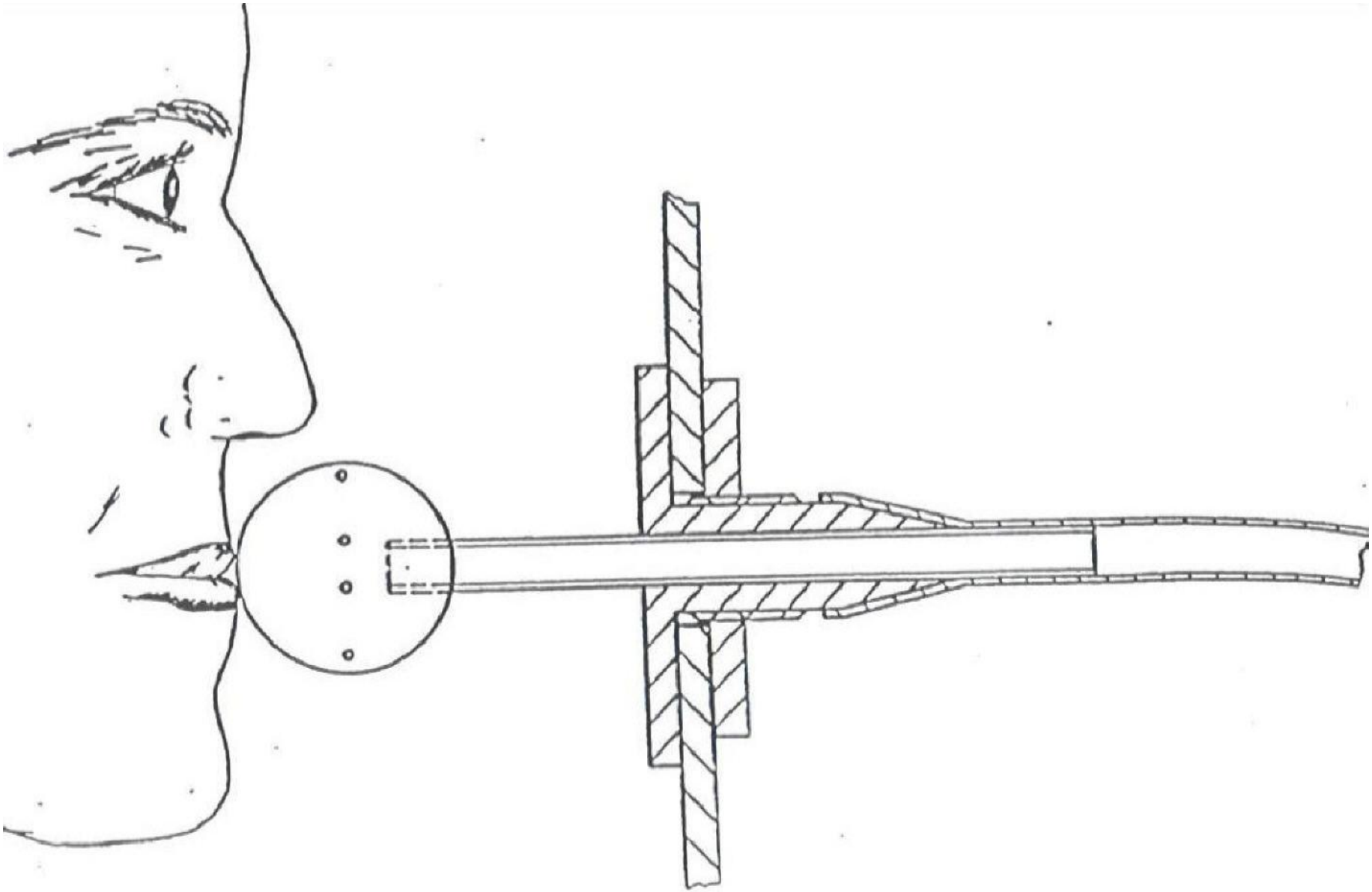
IN-MASK SAMPLING

With a face seal leakage of nominally 6.5% (PF=15), calculated PF of between 6 and 100 were obtained depending on the position of the probe and the site of the leakage path

Bostock (1988)

IN-MASK SAMPLING

Bostock (1988) led to adoption of large diameter deep probe in the relevant European Standards



EFFECT OF PROBE POSITION – FFP3 DEVICE

Leak Posn	Large Dia Deep	Liu Surf	Liu Deep
Temple	1	0.5-1	0.5-1
Chin	1	0.1-0.5	0.05-1
Neck	1	0.1-1	0.1-1

EFFECT OF PROBE POSITION- CONCLUSION

Non-Bostock sample can introduce underestimate of in-mask contaminant levels by up to a factor of 20

UK v US APF

The UK APF tend to be lower than the corresponding APF from ANSI Z88.2 as the latter is partly based on simulated workplace data

QUESTION

Are simulated workplace data suitable for identifying "corresponding limits of use"?

DATA COMPARISON FULL FACE PAPR (PF)

Device	Lab	WPF	Sim WPF
R2	>50.000	55	11,000
R3	>50,000	49	22,500
R4	>50,000	8.4	998

WPF - Howie et al (1996)

Sim WPF - Johnston et al (2000)

DATA COMPARISON VARIOUS (PF)

Device	WPF	Sim WPF
MSA PAPR	gm 35[1]	>1,700[2]
AF Blasting Helmet	2,900[3]	>40,000[3]

1 Myers & Peach (1983), 2 Ayer (1981), 3 Parker et al (1997)

SimWPF v WPF

SimWPF = ~20-200xWPF

RELEVANCE OF SIMULATED WPF STUDIES

Current simulated WPF studies are not a suitable basis for establishing the "limiting conditions of use"

PROPOSED TECHNIQUES FOR IMPROVING RPE PERFORMANCE

EN529 indicates, Appendix E.2.1 that:

"Fit checking provides a simple assessment of the correct fitting of a facepiece …"

WHAT IS FACEPIECE FIT TESTING?

"It is a method for checking that a tight fitting facepiece matches the person's facial features and seals adequately to the wearer's face.

It will also help to ensure that incorrectly fitting facepieces are not selected for use."

ID 282/28, HSE (2003)

WHAT IS FACEPIECE FIT TESTING?

"Fitting tests only identify gross misfits and do not guarantee adequacy of fit."

BS 4275:1997

WHAT IS FACEPIECE FIT TESTING?

Which, is correct, or is either correct?

Fit testing identifies good fit

Fit testing identifies gross misfits only

EXAMINATION OF THE LITERATURE

The WPF literature was searched for papers which provided data which permitted the relationship between QnFF and WPF to be determined or in which the author(s) comment on analysis of such

COMMENTS IN THE LITERATURE

"Quantitative fit testing cannot be used to quantitatively predict workplace performance of respirators for an individual."

Dixon & Nelson (1984)

COMMENTS IN THE LITERATURE

"The lack of a demonstrated association between quantitative fit factors obtained by these PAPRs and the level of protection they provide in the workplace brings into question the appropriateness of using quantitative fit factors as presently determined as the original basis for the PAPR classification of of 1000."

Myers et al (1984)

COMMENTS IN THE LITERATURE

"No relationship was found between the Quantitative Fit Factors measured by the Portacount and the WPF obtained for dual cartridge half-mask negative pressure respirators."

Gaboury and Burd (1989)

COMMENTS IN THE LITERATURE

"The quantitative fit factors that were obtained did not predict which workers would have the highest or lowest WPF. Although the data were limited, it appears there was no correlation between WPF and the quantitative fit factor."

Colton, Johnston, Mullins et al (1989)

COMMENTS IN THE LITERATURE

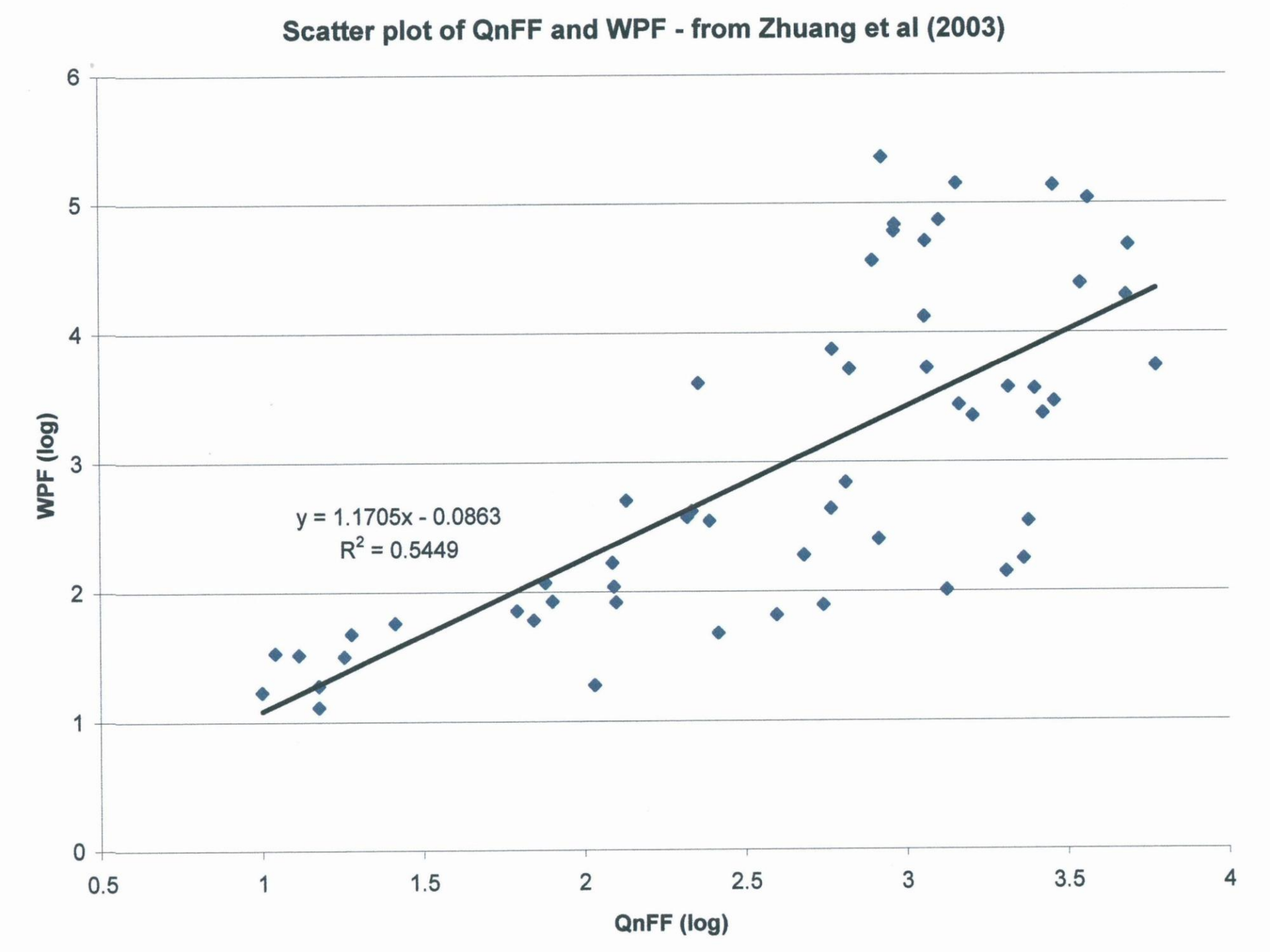
"No significant correlation between the WPF values and the quantitative fit testing data were found in this study."

Myers, Zhuang, Nelson et al (19??)

COMMENTS IN THE LITERATURE

"… FF was shown to be a meaningful indicator of respirator performance in actual workplace environments."

Zhuang et al (2003)


Scatter plot of QnFF and WPF - from Zhuang et al (2003)
WPF (log)
QnFF (log)
y = 1.1705x - 0.0863
R2 = 0.5449
0
1
2
3
4
5
6
0.5
1
1.5
2
2.5
3
3.5
4

HOWIE et al (1996) data

In a study of PAPR during asbestos removal operations, investigators undertook the standard CEN leakage test to identify suitable PAPR and the WPF for the investigators were also measured

HOWIE et al (1996) data

All investigators achieved QnFF>100,000 for their study respirators as measured for the same individual respirators using the same in-mask probes as used during the field study

HOWIE et al (1996) data

*Investigator 75th percentiles**	
H	*276*
J	*231*
W	*130*

** Data were too sparse to permit estimation of >75th percentiles*

HOWIE et al (1996) data

Given that all investigators had achieved a QnFF > 100,000, the finding of a 75th percentile WPF of <300 suggests that QnFF in this study did not usefully indicate likely performance in the workplace

HOWIE et al (1996) data

Investigator training and fit testing therefore did not significantly improve the protection obtained in the workplace compared with relatively untrained workmen

HOWIE et al (1996) data

Statistically, the WPF achieved by the investigators did not differ from that achieved by the workmen

The workmen's 95th%ile WPF was 42

SUMMARY

Only one published study demonstrates a useful relationship between QnFF and WPF, and that interpretation was valid only for WPF <100

CONCLUSION

On the available data QnFT cannot be used to identify that a given facepiece fits a given individual

SO WHAT?

If an individual is given an impression that his RPE provides a good fit he may put himself at risk by failing to minimise contaminant emissions and/or may enter areas he would otherwise avoid

WHAT CAN QnFT ACHIEVE?

It might be able to identify gross misfits, but this is unproven as yet

However, fit testing is an excellent indoctrination and training aid

WORKPLACE PERFORMANCE OF PHPD

STANDARD LABORATORY TESTS

At each frequency, the difference between the uncovered (unoccluded) ear and the covered (occluded) ear is described as the attenuation at that frequency

STANDARD LABORATORY TESTS

From these test data the "Assumed Attenuation" at each frequency is given by; the mean attenuation minus two standard deviations in most countries; mean minus 1 standard deviation in the UK

PHPD SELECTION GUIDANCE IN THE USA

Most PHPD suppliers in the USA recommend that the Noise Reduction Ratio (NRR), the US equivalent of the Assumed Attenuation, be halved

HEARING PROTECTOR PERFORMANCE

The HSE presumes that hearing protector performance measured in the laboratory is a valid basis for selecting devices for use in the workplace

HEARING PROTECTOR PERFORMANCE

Do laboratory attenuations adequately predict attenuations in real workplaces?

HEARING PROTECTORS

Earplugs

"Laboratory attenuation should be de-rated by 60% to rate workplace performance adequately"

Edwards et al (1977)

HEARING PROTECTORS

400 workers, 6 types of earplugs

"assumed attenuation should be drastically reduced"

Alberti (1981)

HEARING PROTECTORS

Fitting of multi-sized plugs:

3 wearers in 10 had difficulty in getting good fit

If larger size selected – no effect on attenuation

If smaller size selected – significant reduction in attenuation

Berger (1981)

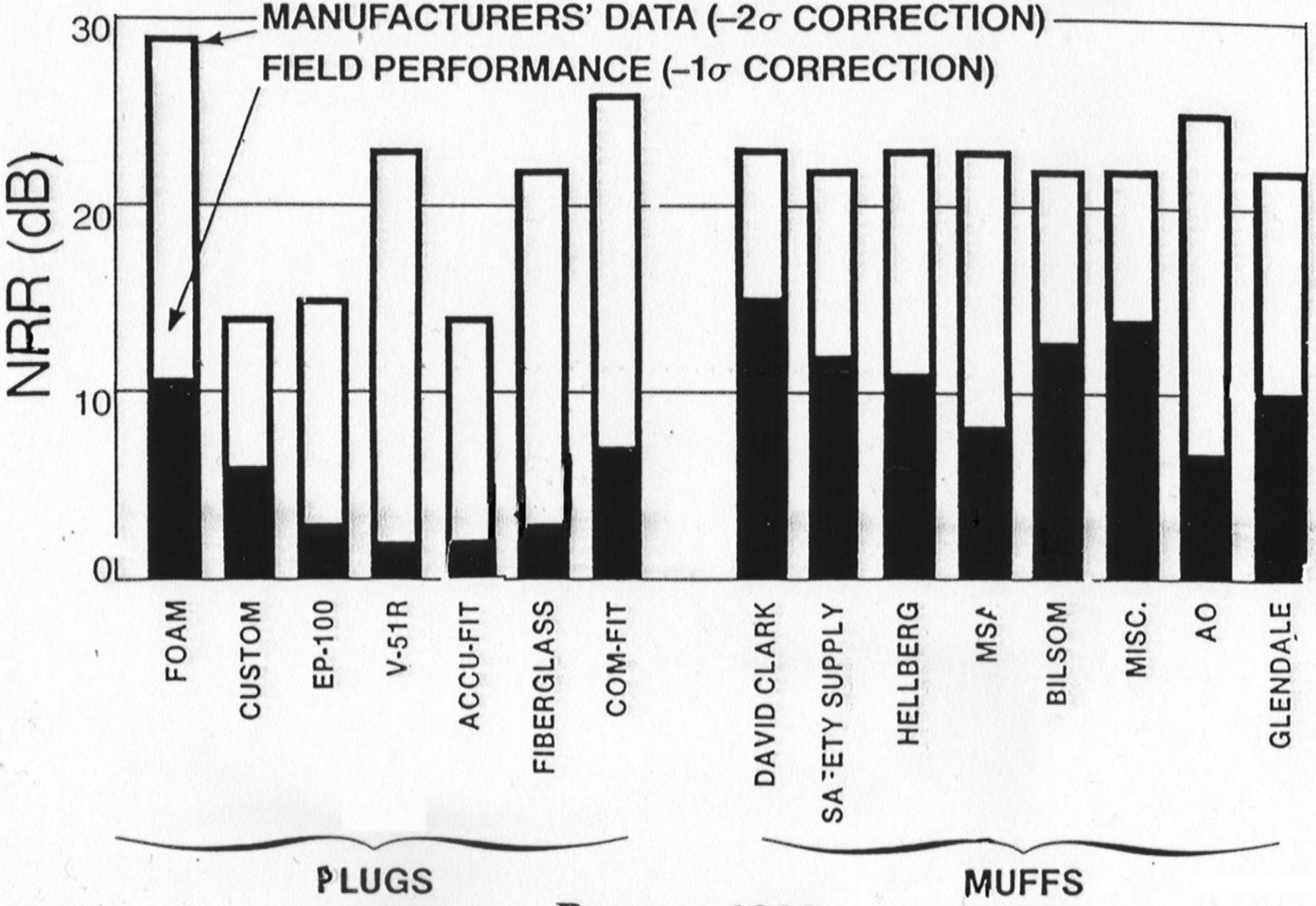
HEARING PROTECTORS

Earplugs

"Current predictive values should be reduced by 50%"

Royster (1981)

LABELED NRRs VS. FIELD PERFORMANCE



Berger, 1983

HEARING PROTECTORS

Earplugs

"Median attenuation:

Laboratory – 29 dB

Workplace – 13 dB"

Lempert & Edwards (1983)

HEARING PROTECTORS

Earplug attenuation (dB):

Device	*Supplier*	*RW*	*S-RW*
Decidamp	*29*	*7*	*22*
EAR	*29*	*4-7*	*>22*
Propp	*22*	*4-0*	*>18*
S Ban (semi)	*19*	*1-3*	*>16*

Behar (1984)

HEARING PROTECTORS

Muff attenuation (dB):

Device	*Supplier*	*RW*	*S-RW*
H7P3E	*25*	*6*	*19*
1776K	*21*	*5-10*	*>11*
204	*22*	*17*	*5*

Behar (1984)

HEARING PROTECTORS

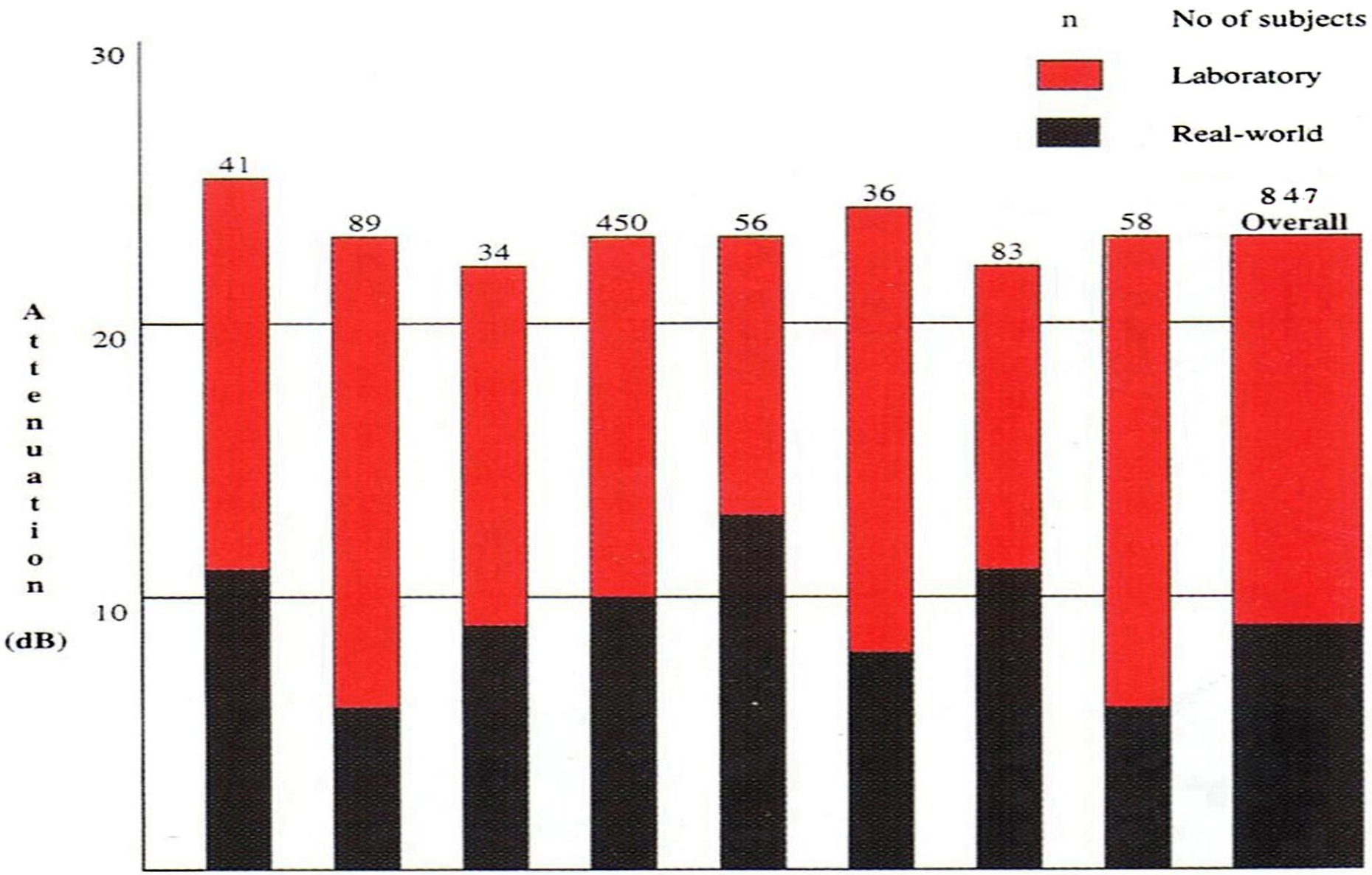
Earplugs – 449 workers, 16 sites

"On average the workers received only 1/3 to 1/2 the total decibel attenuation claimed by the manufacturers"

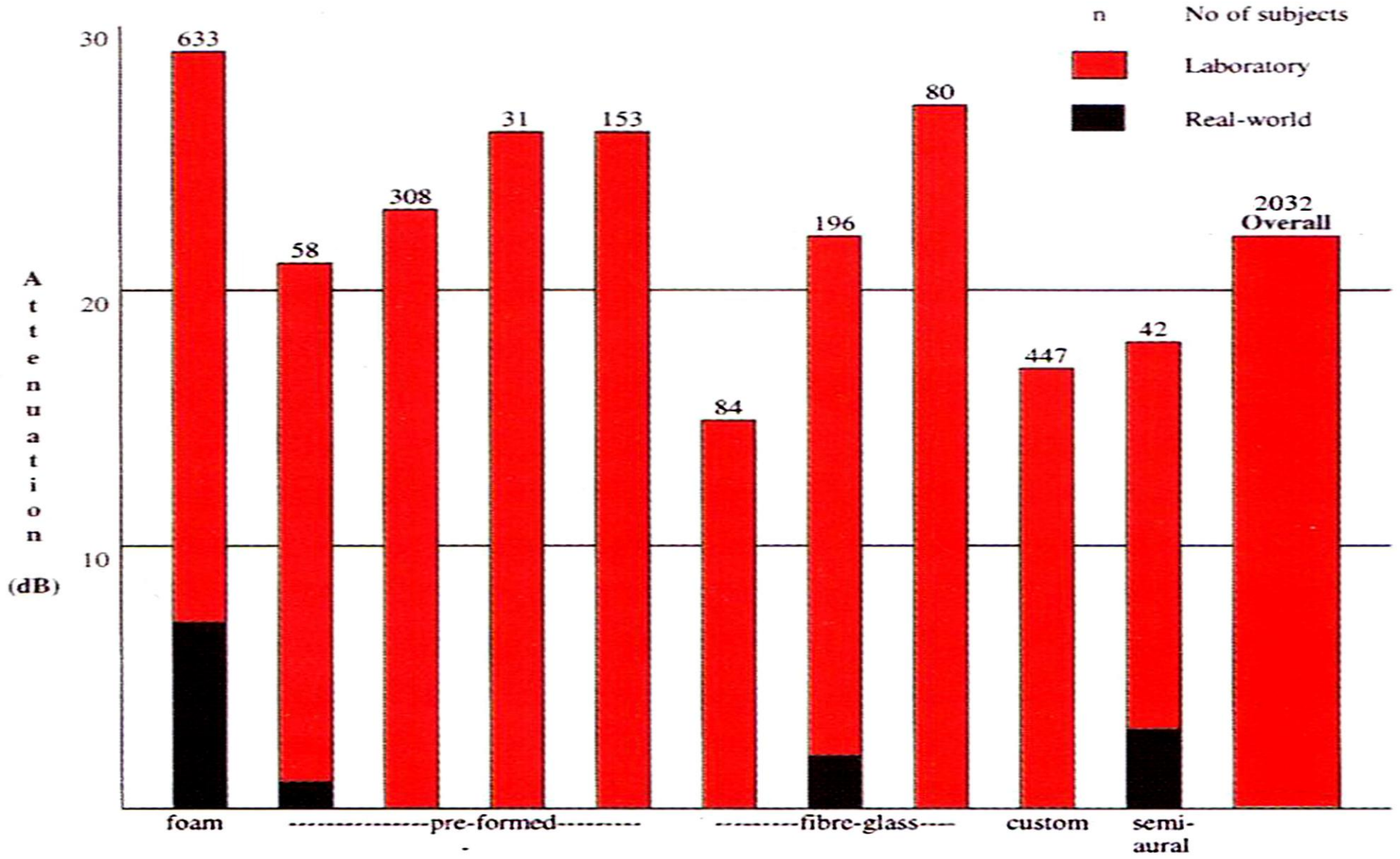
Green et al (1989)

HEARING PROTECTORS

From Hempstock & Hill (1990) Real-World means are lower than Laboratory means and Real-World standard deviations are larger than Laboratory standard deviations



Comparison of laboratory and real world assumed attenuation for ear muffs (mean minus 2 sd), from Berger et al (1996)



Comparison of laboratory and real-world assumed attenuation for ear plugs (mean minus 2 sd), from Berger et al (1996)

CONCLUSION 1 - HEARING PROTECTORS

Results from Standard laboratory tests cannot be used to define corresponding limits of use for PHPD in the workplace

CONCLUSION 2 - HEARING PROTECTORS

Ear muffs should not be assumed to provide more than 5 dB attenuation and ear plugs should not be assumed to provide any attenuation unless relevant neutral workplace data are available

WHY DO PHPD PERFORM SO POORLY?

Ear muffs should not be assumed to provide more than 5 dB attenuation and ear plugs should not be assumed to provide any attenuation unless relevant neutral workplace data are available

WHY DO PHPD PERFORM SO POORLY?

Plugs worn for 155-195 min:

VR-51R – 40% of wearers had total loss of seal

Foam – no significant change

Fibreglass – significant reduction

Berger (1981)

WHY DO PHPD PERFORM SO POORLY? Plugs worn for 60-75 min:

Foam – little change

Pre-moulded silicone – 6 dB reduction

Self-moulded fibreglass – 10 dB reduction

Abel & Rokas (1986)

WHY?

Effect of industrial use on muffs:

Age	Attn (db) @ Frequency (Hz)							
	63	125	250	500	1k	2k	4k	8k
New	12	6	12	18	30	29	29	28
6 wk	7	4	5	14	23	26	22	20
1 yr	4	3	5	14	24	28	29	20

Rawlinson & Wheeler (1987)

CONCLUSIONS

Attenuation of plugs can fall markedly in less than 60 min

Muff performance can fall significantly from 6 weeks use

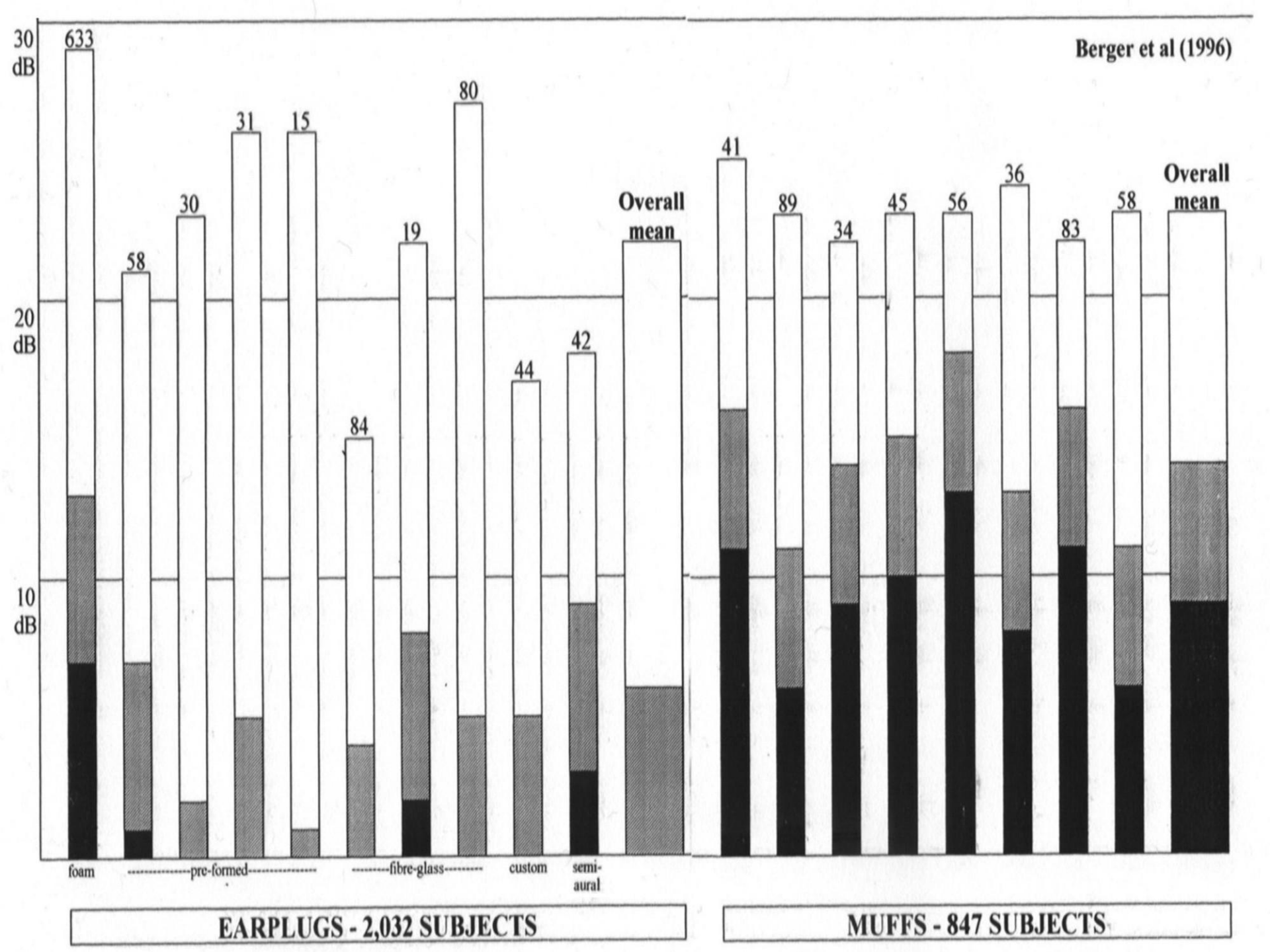
CONCLUSIONS

Results from standard laboratory tests cannot be used to define corresponding limits of use for Hearing Protectors in the workplace

WHY?

Possible reasons:

Standard laboratory tests are of short duration in clean environments involving stationary, non-talking and non-chewing subjects


Berger et al (1996)
30 dB
20 dB
10 dB
633
58
30
31
15
84
19
80
Overall mean
44
42
41
89
34
45
56
36
83
58
Overall mean
foam
pre-formed
fibre-glass
custom
semi-aural
EARPLUGS - 2,032 SUBJECTS
MUFFS - 847 SUBJECTS

RECOMMENDATION 1

Earplugs should be assumed to provide no attenuation unless real workplace data are available

RECOMMENDATION 2

Muffs should not be assumed to provide >5 dB attenuation unless it has been proven in real workplaces that more can be achieved with the specific model of interest

RECOMMENDATION 3

Personal hearing protectors should not be used unless high performance audiometric testing is an inherent component of the hearing protection programme

WARNING

If PHP suppliers, government Inspectors or hygienists act in a manner that puts wearers' hearing at known risk, all are liable under both criminal and civil law!

CAN R-W PERFORMANCE BE PREDICTED FROM LAB RESULTS?

FROM HEMPSTOCK & HILL (1990)

EAR plug:

Lab			Real World		
mn	sd	mn-2sd	mn	sd	mn-2sd
35.9	6.6	22.7	24.4	8.7	7.0

FROM HEMPSTOCK & HILL (1990)

EAR plug:

Lab			Real World		
mn	**sd**	**mn-2sd**	**mn**	**sd**	**mn-2sd**
35.9	**6.6**	**22.7**	**24.4**	**8.7**	**7.0**

The Real-World mean – 2 sd could be obtained by subtracting 4 lab sd from the lab mean

FROM HEMPSTOCK & HILL (1990)

Possible Lab sd multipliers:

Plugs –	**Bilsom POP**	**3.4**
	Bilsom SOFT	**6.6**
	EAR	**4.4**
Muffs-	**Safir ED/IS**	**3.9**
	Auralguard	**4.4**
	Bilsom Comfort	**3.2**
	Hellberg 26007	**4.5**

COMMENT

Real-World mean – 2 sd data might be able to be predicted by subtracting 3-7 lab sd from lab means

BUT

the above would need to be corroborated from a much larger data set

GENERAL OBLIGATIONS ON EMPLOYERS

89/391/EEC – Article 6.2.(h)

"giving collective protective measures priority over individual protective measures;"

CONSEQUENCES OF LOWER THAN EXPECTED PPE PERFORMANCE

The critical consequence of real-world PPE performance is that much greater emphasis must be put onto substitution, complete enclosure etc. than is currently the case

CONSEQUENCES OF LOWER THAN EXPECTED PPE PERFORMANCE

For powered devices fitted with P3 filters and assuming an APF of 40 rather than an NPF of 2,000, asbestos strippers removing amosite would have a maximum out-of-mask fibre concentration of 12,000 fibres/m^3 rather than 600,000 fibres/m^3 to ensure that the MTR proposed by the Health Council of the Netherlands is not exceeded

CONSEQUENCES OF LOWER THAN EXPECTED PPE PERFORMANCE

From personal experience the careful commercial removal of asbestos insulation boards or pipe lagging containing amosite is likely to generate at least 100,000 fibres/m^3

CONSEQUENCES OF LOWER THAN EXPECTED PPE PERFORMANCE

It will therefore be necessary to reconsider how high risk activities are planned, carried out and supervised and how the Directives are enforced