How accurate and precise should exposure assessment and control tools be?

Hans Kromhout, IRAS, Universiteit Utrecht

Institute for Risk Assessment Sciences

Simple question deserves a simple answer

Very accurate and very precise

Because

- Workplace conditions incorrectly assessed as *safe* might lead to health risks of employees
- Workplace conditions incorrectly assessed as *unsafe* will lead to over-engineering and unnecessary high costs for employers

Very accurate and very precise

The problem with occupational exposures

Enormous intrinsic variability

- 10 to 150 fold differences in airborne concentrations between days are common
- Differences between individuals in average exposure do exist (human factor)

Therefore

- We moved (in 1960) from static to personal measurements (to come closer to the true exposure)
- We kept improving our measurement devices and analytical methods in order to meet accuracy and precision standards

Ann. occup. Hyg., Vol. 47, No. 3, pp. 179–185, 2003

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DOI: 10.1093/annhyg/meg030

Commentary

To celebrate the BOHS 50th anniversary this year, we are reproducing in our on-line edition 'classic papers' from past issues of the Annals, *with accompanying commentaries in the print and on-line edition. For this issue, the classic paper we reproduce is Sherwood RJ, Greenhalgh DMS. (1960) A personal air sampler. Ann Occup Hyg; 2: 127–32.*

The Beginning of the Science Underpinning Occupational Hygiene

J. W. CHERRIE

University of Aberdeen and the Institute of Occupational Medicine, Edinburgh EH8 9SU, UK

Received 8 January 2003; in final form 20 January 2003

Sherwood and Greenhalgh's 1960 paper is a seminal one for the development of the science of human exposure. There are three key elements in the paper that deserve to be highlighted: the development of the first personal sampling pump and sampling head; the first comparison between personal sampling and static sampling; the first observation of the possible effect of personal sampling on the individual being sampled.

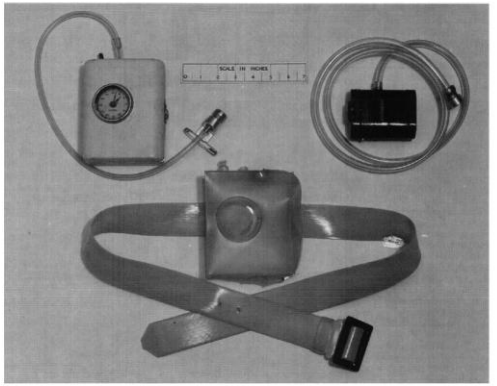
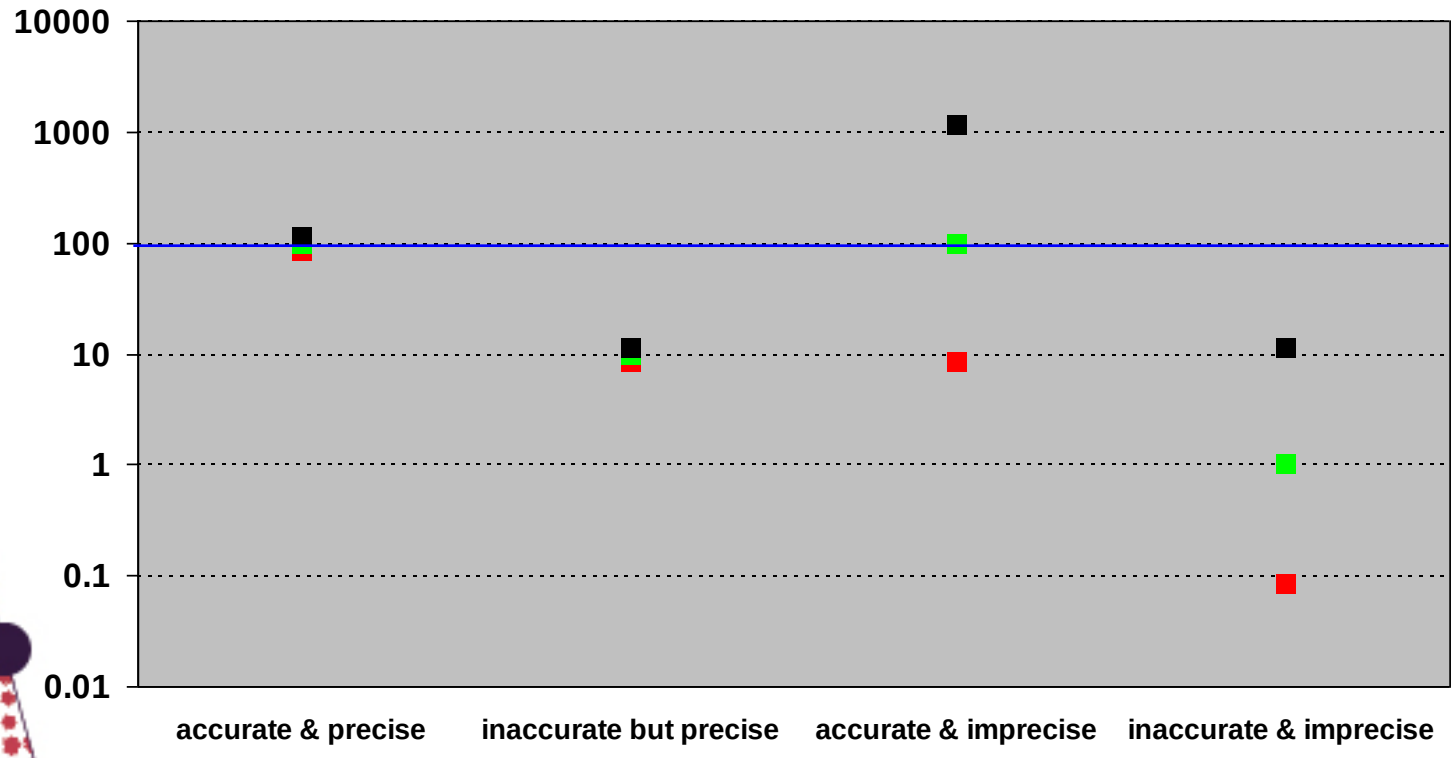


Fig. 2. The Mk1 and Mk2 personal sampling pumps invented by Sherwood and Greenhalgh.

Accuracy and precision
exposure = 100



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Requirements for measurement methods

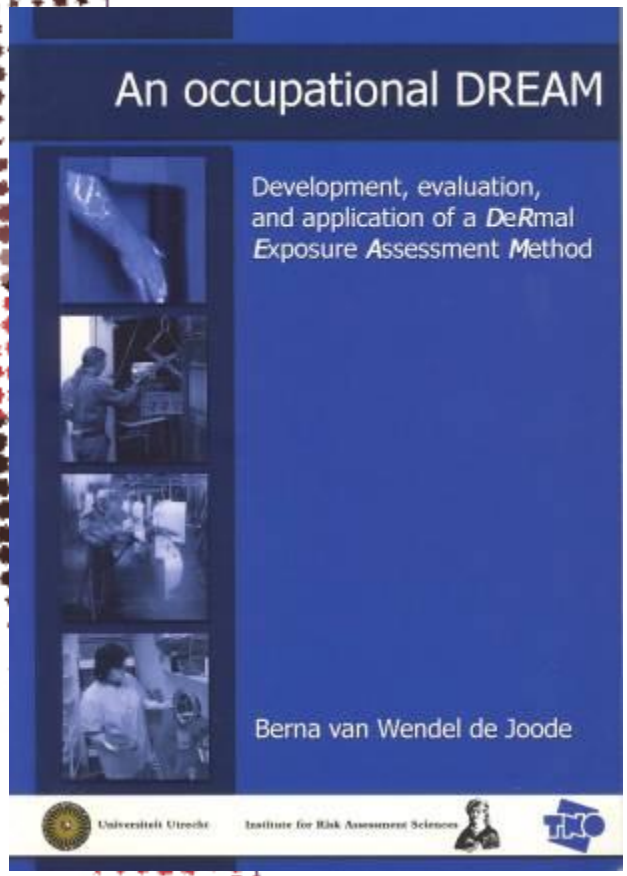
Coefficient of variance below 10%

Bias as low as possible
(reduction through calibration)

Requirements to "sell" tools as validated

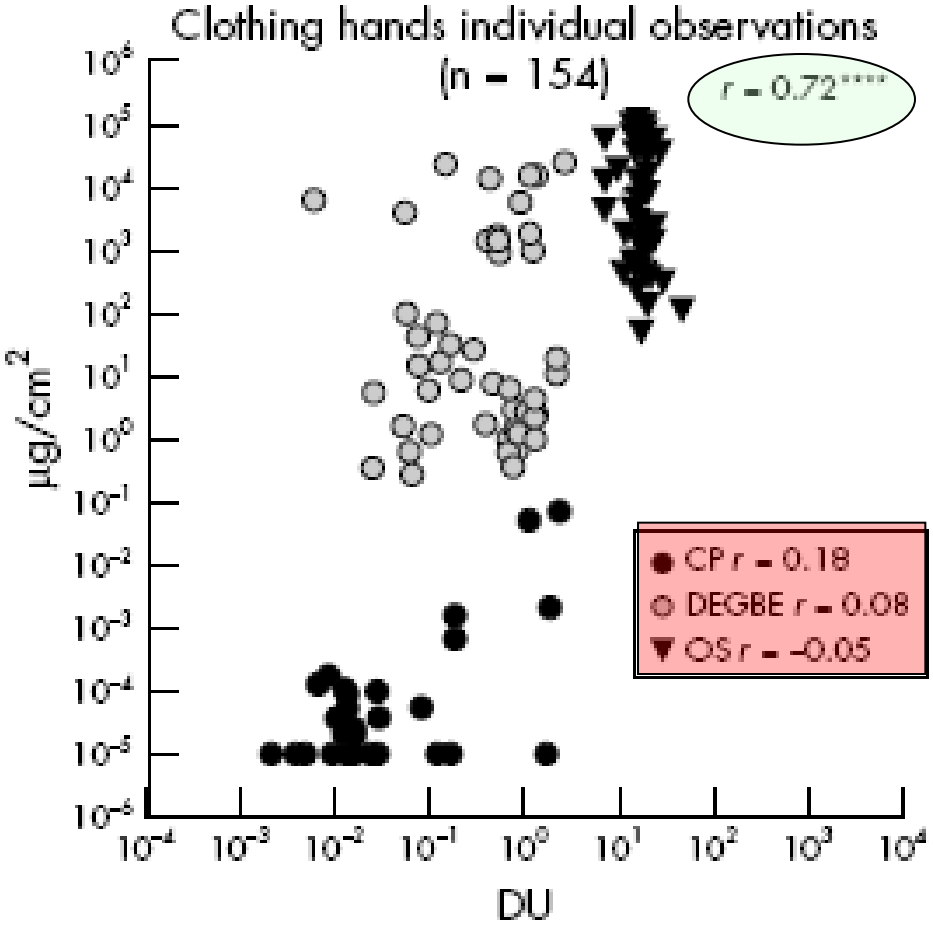
- To describe the ins- and outs- of a tool
- To test the precision (reliability) by having multiple users assess similar situations
- To assess the validity of the tool with a "golden" standard
- To apply the tool under real-world conditions

A good example
DREAM



- van Wendel de Joode B, Brouwer DH, Vermeulen R, Van Hemmen JJ, Heederik D, Kromhout H. ***DREAM: a method*** for semi-quantitative dermal exposure assessment. Ann Occup Hyg. 2003 Jan;47(1):71-87.
- van Wendel de Joode B, van Hemmen JJ, Meijster T, Major V, London L, Kromhout H. ***Reliability*** of a semi-quantitative method for dermal exposure assessment (DREAM). J Expo Anal Environ Epidemiol. 2005 Jan;15(1):111-20.
- van Wendel de Joode B, Vermeulen R, van Hemmen JJ, Fransman W, Kromhout H. ***Accuracy*** of a semiquantitative method for Dermal Exposure Assessment (DREAM). Occup Environ Med. 2005 Sep;62(9):623-32.
- van Wendel de Joode B, Bierman EP, Brouwer DH, Spithoven J, Kromhout H. ***An assessment of dermal exposure*** to semi-synthetic metal working fluids by different methods to group workers for an epidemiological study on dermatitis. Occup Environ Med. 2005 Sep;62(9):633-41.

DREAM accuracy



"Only for situations with large contrasts in dermal exposure (2-3 orders of magnitude) DREAM estimates could be used after calibration as quantitative proxies"

A bad example
EASE

The EASE model has been ***under development and in use since the early 1990s.***

The Health and Safety Executive (HSE) developed EASE in collaboration with the Health and Safety Laboratory (HSL) as a general model to predict workplace exposure to substances hazardous to health, which would be applicable to a wide range of substances and circumstances of use.

- Tickner J, Friar J, Creely KS, Cherrie JW, Pryde DE, Kingston J. The ***development of the EASE model***. Ann Occup Hyg. **2005** Mar;49(2):103-10.
- Hughson GW, Cherrie JW. ***Comparison*** of measured dermal dust exposures with predicted exposures given by the EASE expert system. Ann Occup Hyg. 2005 Mar;49(2):111-23.
- Cherrie JW, Hughson GW. The ***validity*** of the EASE expert system for inhalation exposures. Ann Occup Hyg. 2005 Mar;49(2):125-34.
- Creely KS, Tickner J, Soutar AJ, Hughson GW, Pryde DE, Warren ND, Rae R, Money C, Phillips A, Cherrie JW. ***Evaluation and further development*** of EASE model 2.0. Ann Occup Hyg. 2005 Mar;49(2):135-45.

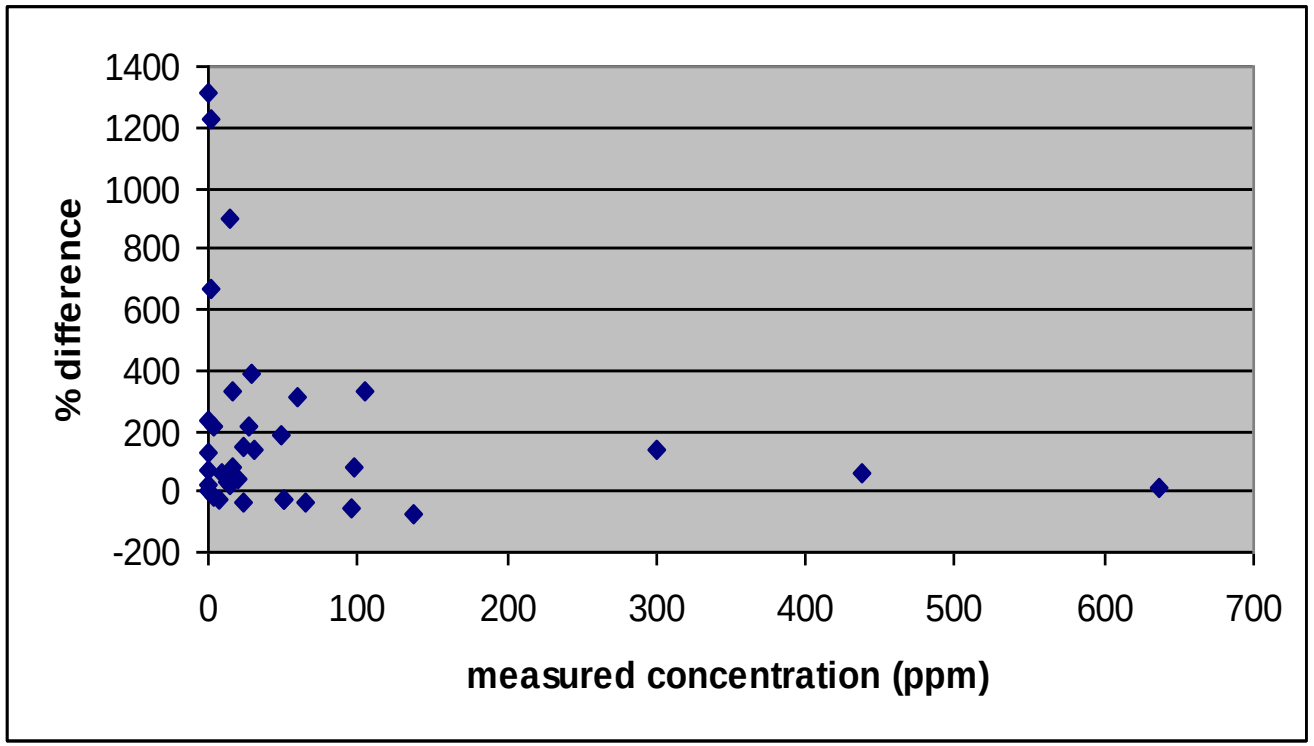
Evaluation and further development of EASE model 2.0

(IOM, 2003)

- Summary
  - "… it is a great simplification of what takes place when people are exposed to chemicals; and this simplification does not incorporate all of the important exposure determinants."
  - "More importantly, it is believed that EASE does not produce estimates of exposure that are unambiguous or complete."
- 4. Review of EASE validation and consistency studies
  - ".., although in fact *there is no indication that EASE is substantially better than a random allocation of exposure range*."
  - It performed less well than a human expert

EASE

How reliable is EASE when estimating the exposure to solvents?



Pre-dominantly over-estimation

Very inaccurate at low exposure levels (4-10 fold too high)

Has anybody used EASE for workplace evaluations?

If yes,

Go back and ask for forgiveness and pray that in the mean time nobody fell ill due to misjudgement and subsequently called Bram Moszkowicz

Modern Tools

- de Stoffenmanager
- Advanced REACH Tool (ART)
- Welding Fume Assistant
- ECETOC TRA

Are they precise and accurate enough and do we know?

Stoffenmanager

Web-based Tool developed for:

- control banding of chemical risks
- **quantitative exposure assessment**
- REACH worker (scenario) exposure assessment

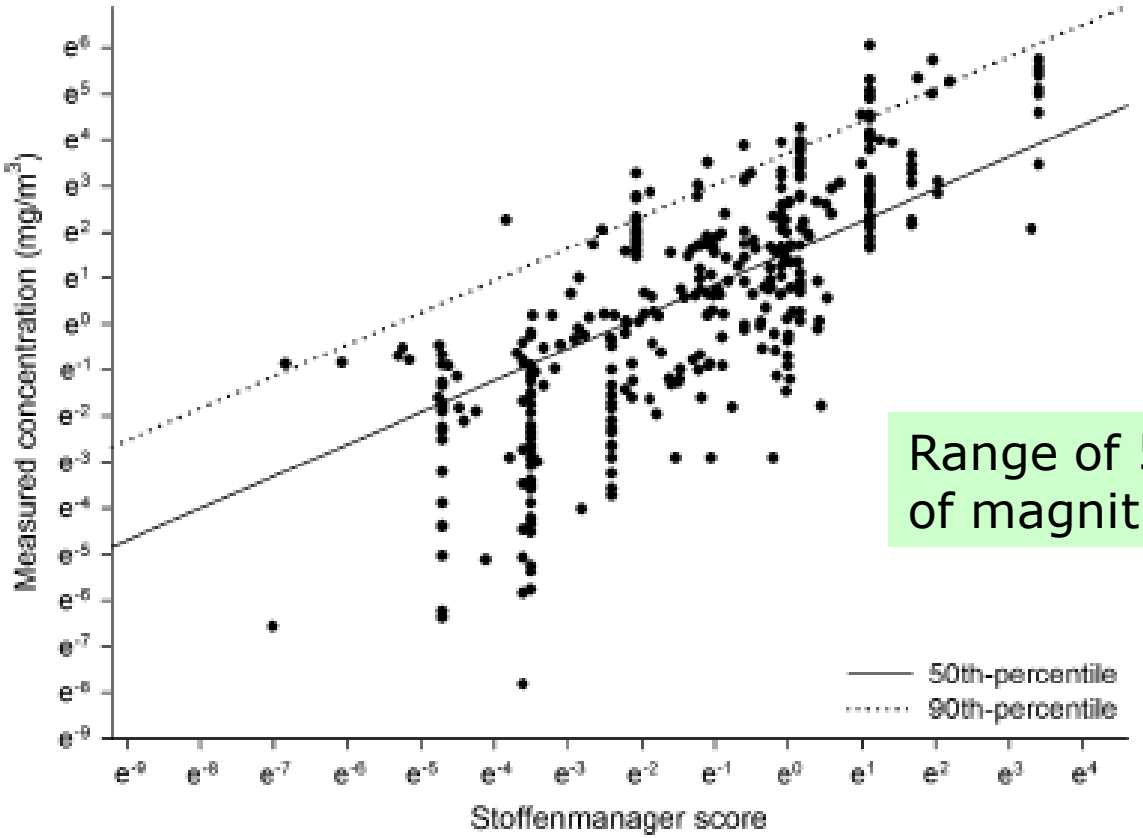
Marquart H, Heussen H, Le Feber M, Noy D, Tielemans E, Schinkel J, West J, Van Der Schaaf D. '**Stoffenmanager**', a web-based control banding tool using an exposure process model. Ann Occup Hyg. 2008 Aug;52(6):429-41. Epub 2008 Jun 27.

Tielemans E, Noy D, Schinkel J, Heussen H, Van Der Schaaf D, West J, Fransman W. Stoffenmanager exposure model: development of a **quantitative algorithm**. Ann Occup Hyg. 2008 Aug;52(6):443-54. Epub 2008 Jul 10.

Schinkel J, Fransman W, Heussen H, Kromhout H, Marquart H, Tielemans E. **Cross-validation** and refinement of the Stoffenmanager as a first tier exposure assessment tool for REACH. Occup Environ Med. 2010 Feb;67(2):125-32. Epub 2009 Sep 22.

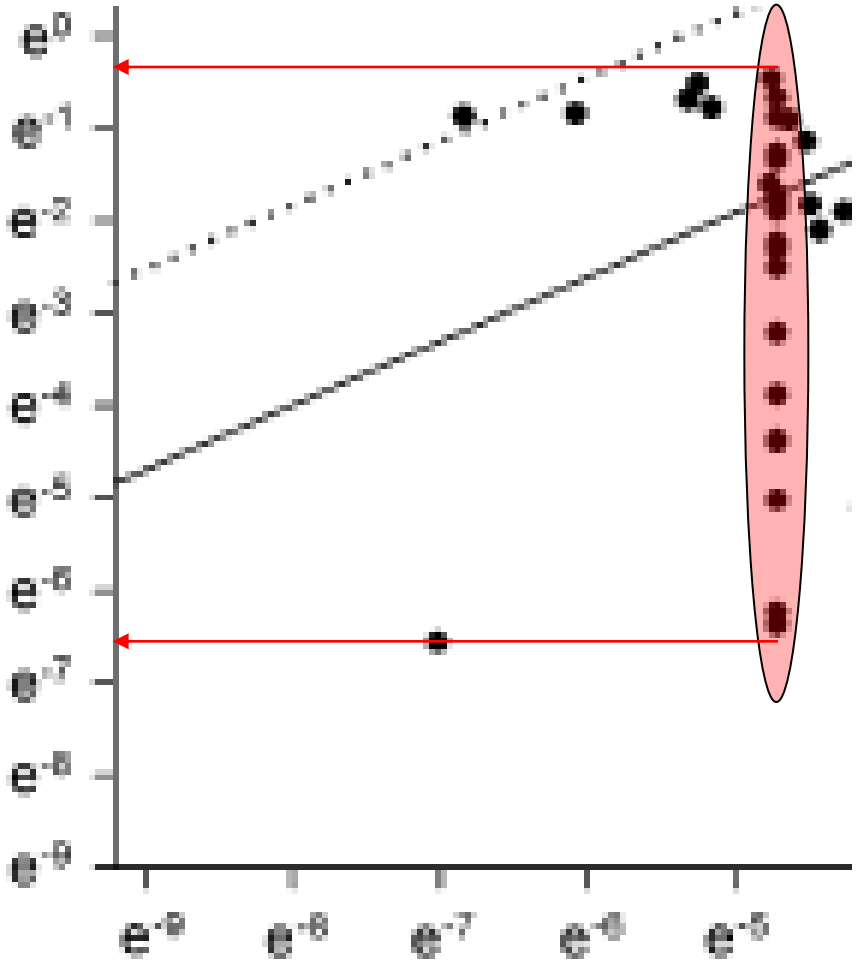
Stoffenmanager accuracy

r_p = 0.72



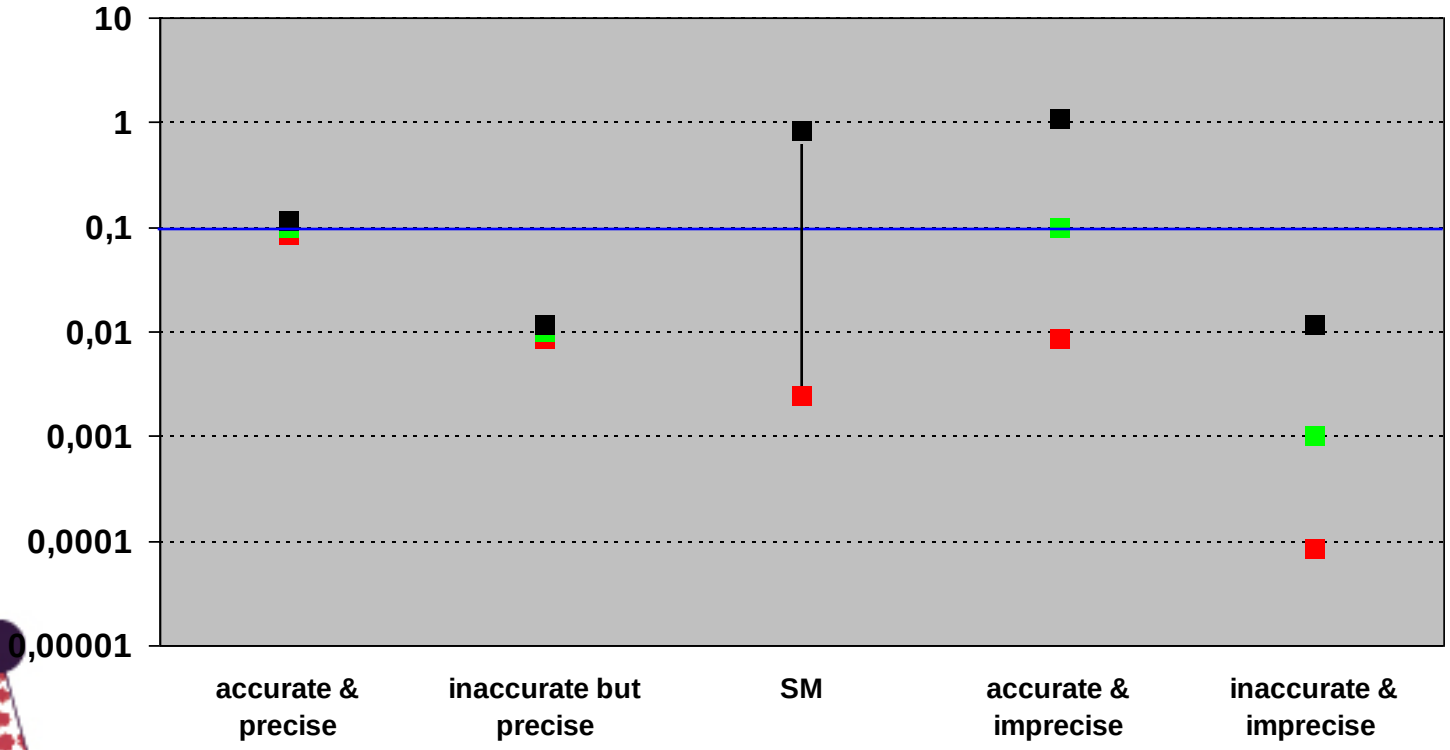
Range of 5-6 orders of magnitude

Stoffenmanager accuracy



3 orders of magnitude uncertainty in dust exposure estimates for situations with similar SM-score!

Precision of SM
(same expert raters)
exposure = 0.1



Despite r=0.72 SM can be very imprecise

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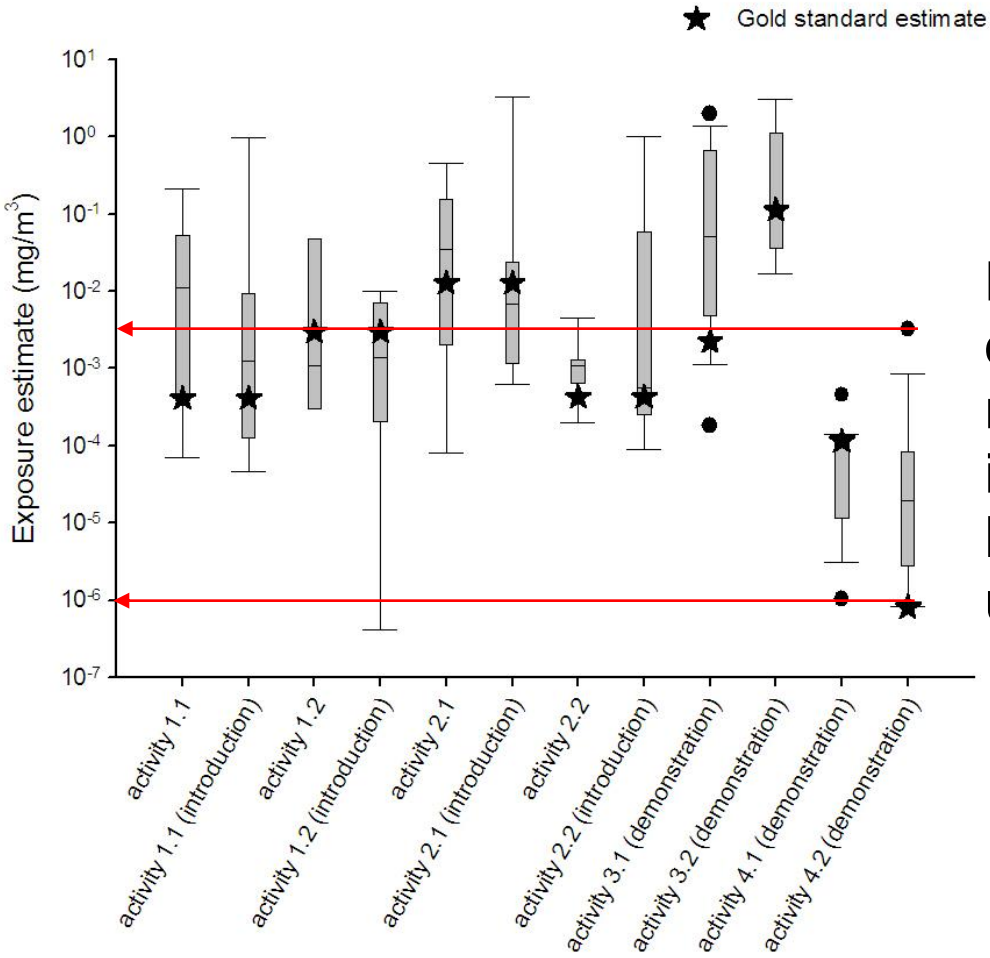
ART Precise/reliable enough?



More than 3 orders of magnitude imprecision between-users/raters

Accuracy of Stoffenmanager

Schinkel et al. 2009

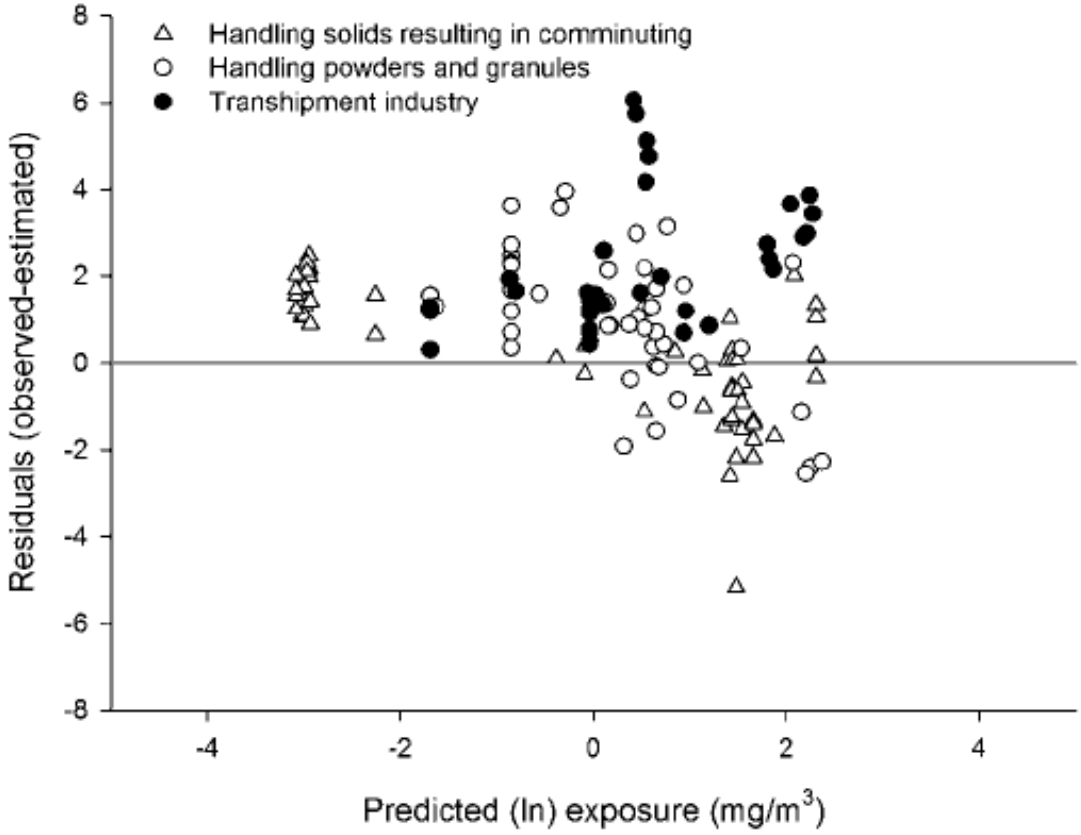
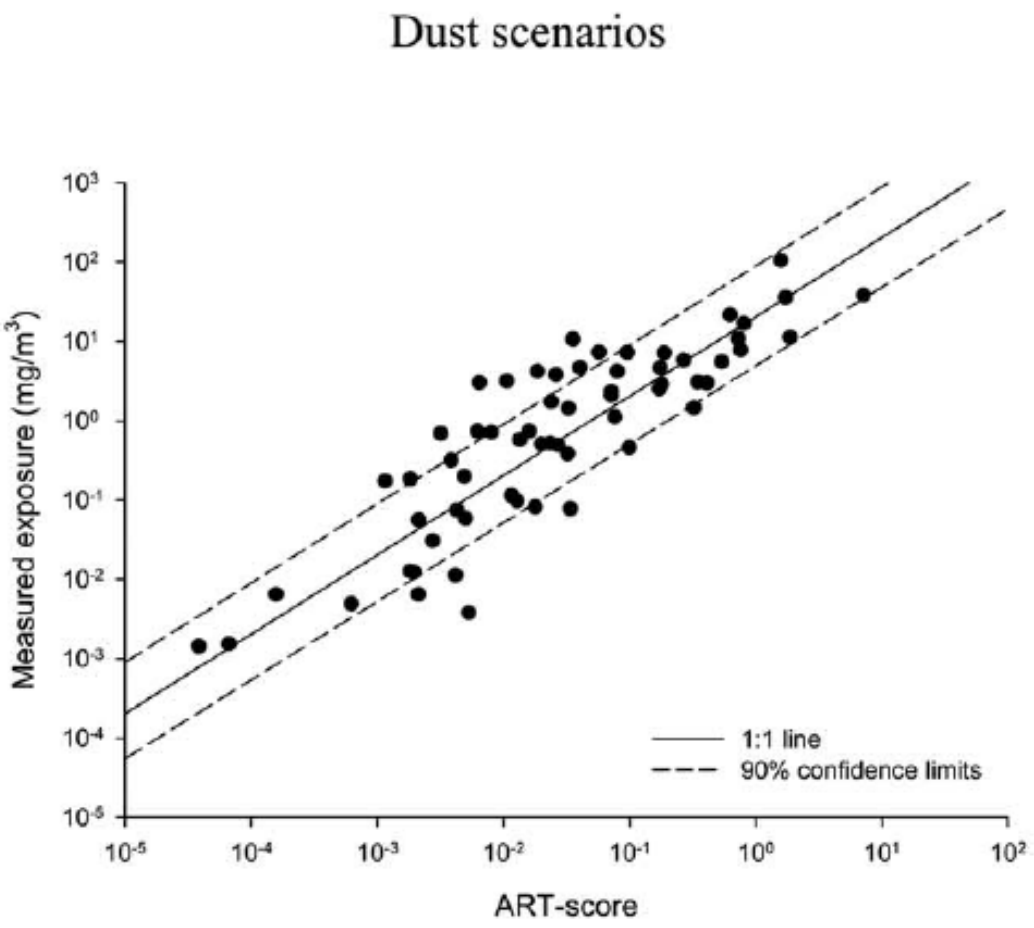


Figure 1 Plot of residuals of measured exposure and estimated exposure as a function of the predicted exposure for handling of solids.

maximum of 3-4 orders of magnitude differences between estimated and measured TWA task-based exposure

Calibration of mechanistic model of ART

Schinkel et al. 2011



maximum of 2-3 orders of magnitude differences between estimated and measured average exposure per scenario

Despite inaccuracy & imprecision, in the mean time on ARBO-Portaal:

"The Dutch Labour Inspectorate ***accepts*** the **quantitative assessment** of exposure of Stoffenmanager as ***a method to evaluate exposure to hazardous agents at the workplace***"

Welding Fume Assistant

De lasrook assistent

Selecteer hieronder de werksituatie waarvan u de blootstelling aan lasrook wilt voorspellen

Meer informatie per vraag wordt gegeven in de toelichting en door de vraagtekens aan te klikken.
In de scroll-down menu's rechts van de vraagtekens zijn alle keuzemogelijkheden opgenomen, deze worden geselecteerd door ze aan te klikken

Factsheets overzicht | Toelichting bij gebruik van de Lasrook Assistent

Toegepaste lastechniek	TIG-lassen
Te bewerken materiaal tijdens de werkzaamheden met de bovengenoemde lastechniek	aluminium
Aanwezigheid van een deklaag (vb coating of vet) op het materiaal	er is WEL een deklaag aanwezig
Inschakelduur van de lasapparatuur	de inschakelduur is minder dan 15% van de werkdag
Type (bron) afzuiging op de werkplek	beweegbare afzuigarm
Type persoonlijke beschermingsmiddelen bij uitvoering van dit proces	vaste lashelm
De stand van het hoofd tijdens de laswerkzaamheden	meestal in de pluim
Er wordt geslepen naast de voorkomende lastaken	☑
Alle lastaken worden door een lasrobot uitgevoerd	☐
Lasrookblootstelling in het verleden (alleen invullen voor schattingen in het verleden)	2006

Bereken de blootstelling

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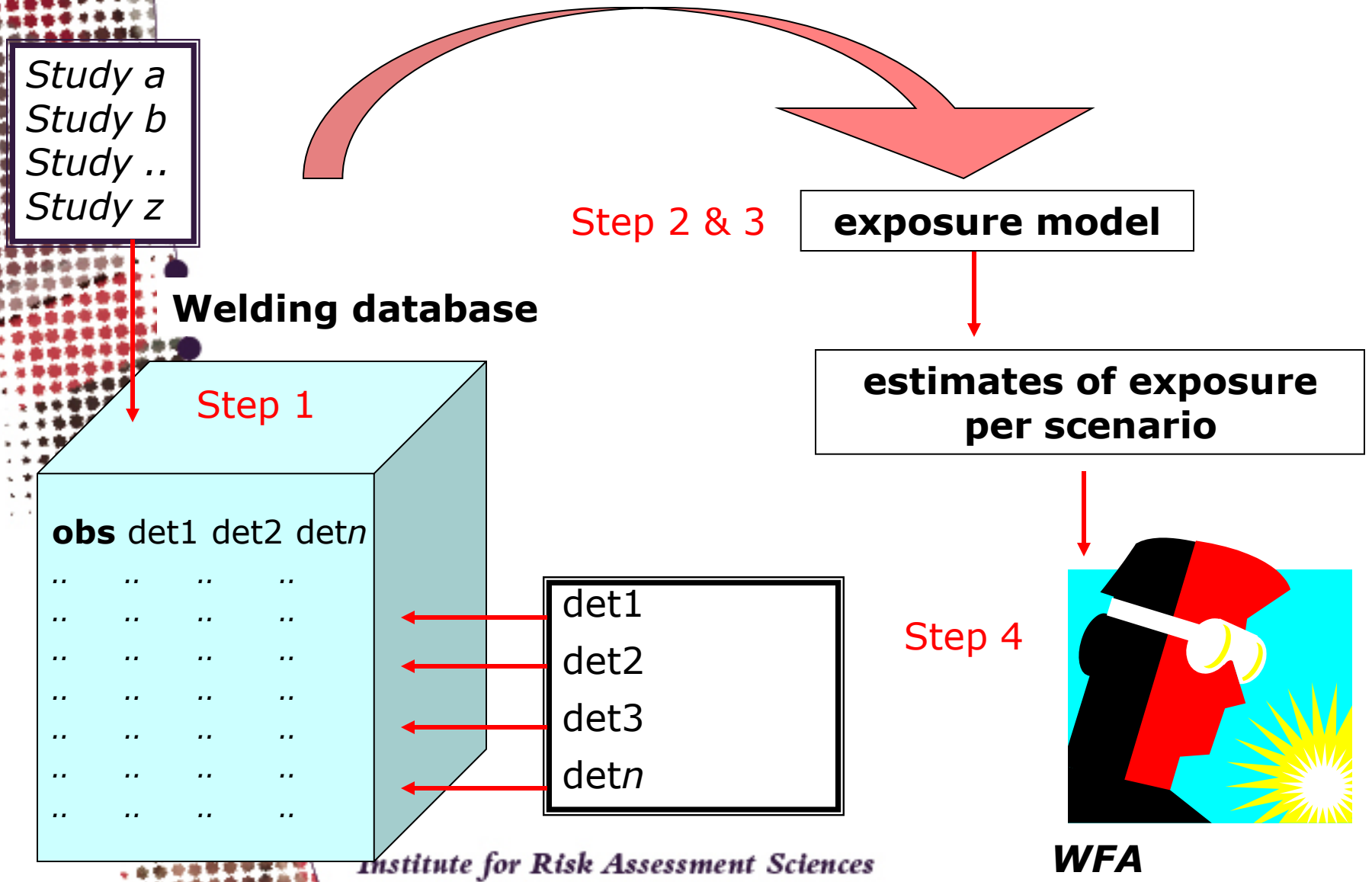
Welding Fume Assistant

Measurement data-driven exposure assessment tool

Based on a large welding fume exposure measurement database (>1000 observations from NL)

- Covering a variety of industries, welding techniques, control measures
- Empirical statistical modeling

in 1 picture...


Study a
Study b
Study ..
Study z
Welding database
Step 1
obs det1 det2 detn
det1
det2
det3
detn
Step 2 & 3
exposure model
estimates of exposure per scenario
Step 4
WFA
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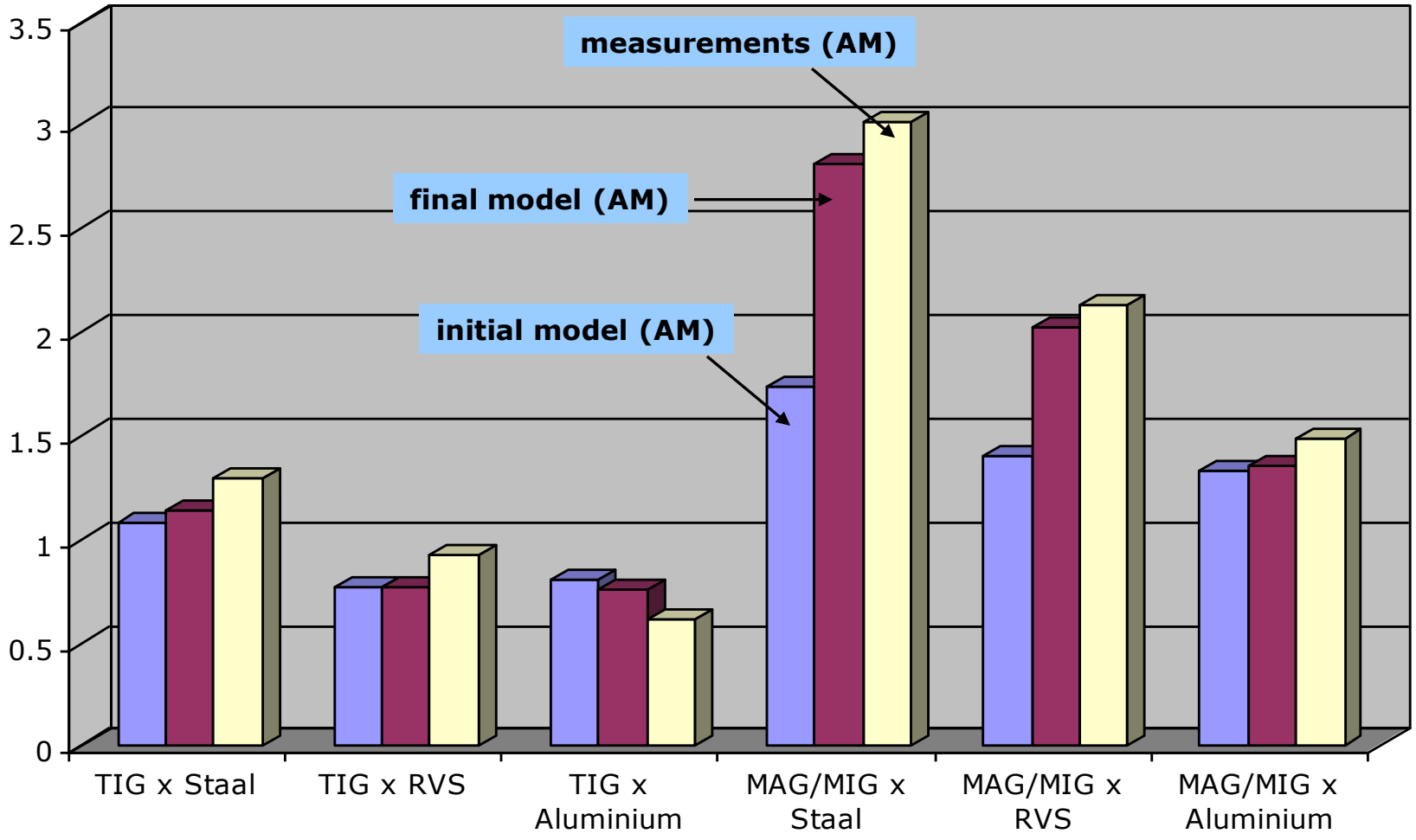
But..... can we rely on it?

59 validation measurements performed:
6 most relevant scenarios
2 more characteristics (determinants) added: grinding / robot welding

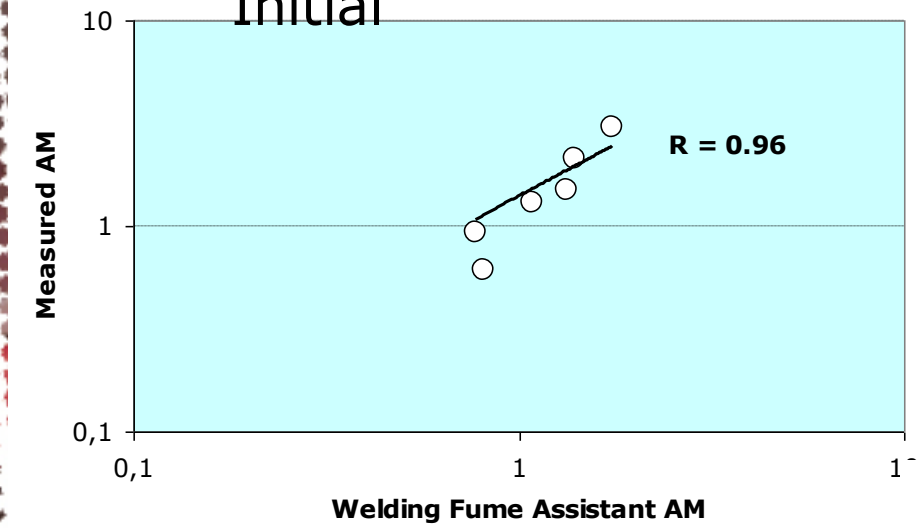


Accuracy of WFA

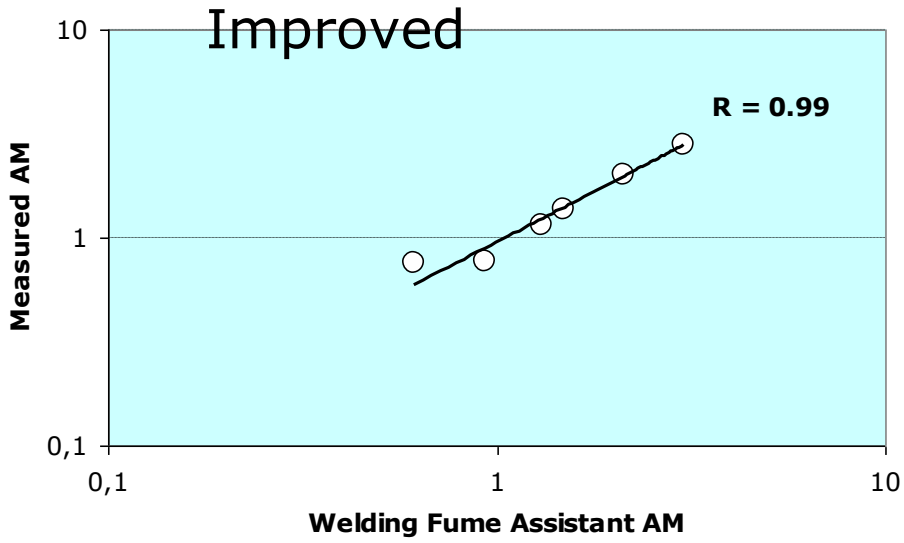
- Differences between prediction and actual exposure (AM) within a factor of 2!
- After adjustment (adding two additional determinants) differences were even less
- Correlation between predicted AMs and measured AMs was (on log scale) **0.96** originally (range of exposures 0.6-3.0 mg/m^3 = half-order of magnitude)
- Correlation between predicted AMs and measured AMs was (on log scale) **0.99** after slight adjustments of model

Accuracy of WFA

Initial



Improved



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Accuracy of WFA

- Differences between prediction and actual exposure (AM) within a factor of 2!
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Classification of tools

SER Leidraad for safe working with chemicals

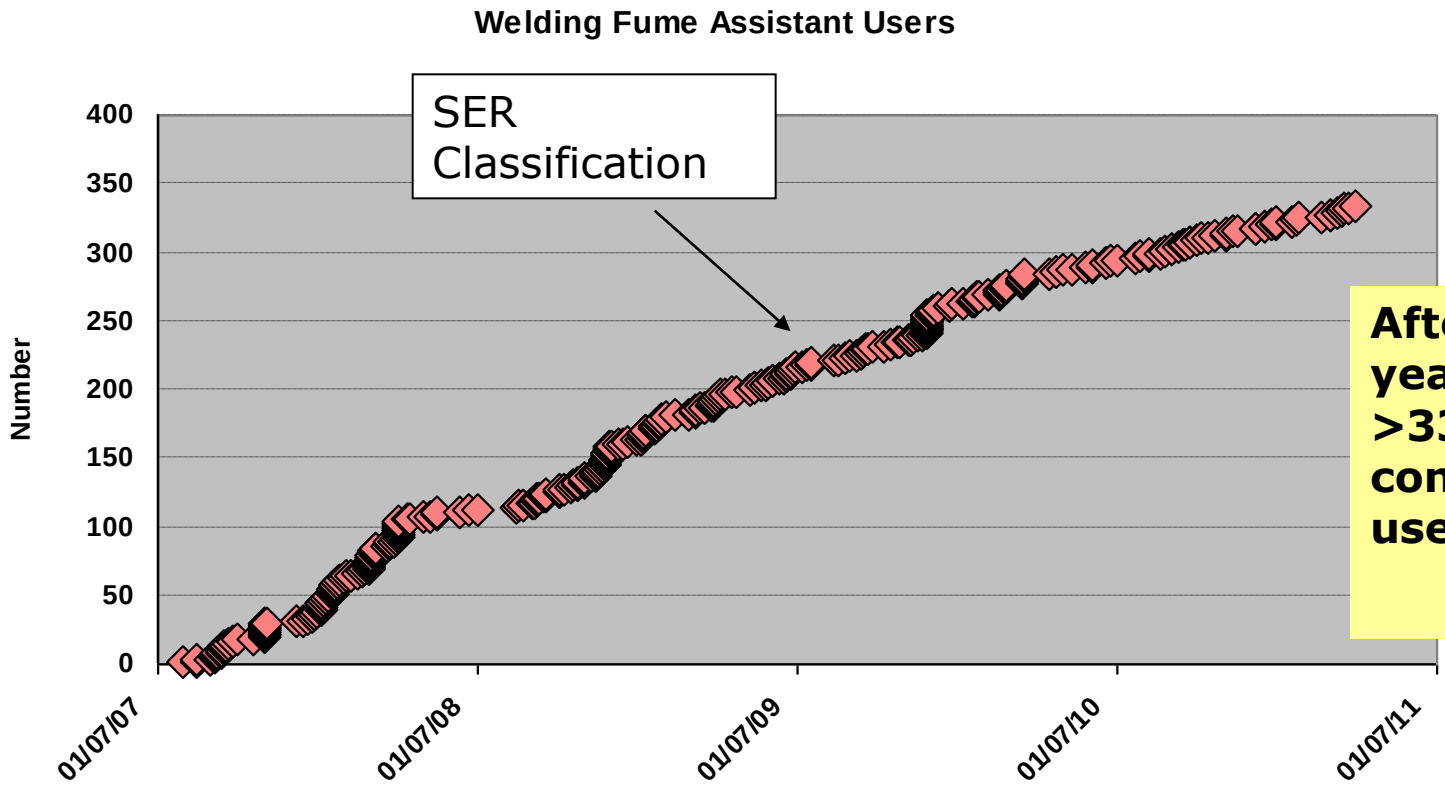
1.	Stoffenmanager	AB
2.	EASE	BA
3.	Welding Fume Assistant	BB

AB: tool delivers a ***safe and reliable result***, but has ***no support*** among social partners

BA: tool delivers a ***result that is probably right***, but insufficient proven. Tool has ***support*** among social partners

BB: tool delivers a ***result that is probably right***, but insufficient proven. Tool has ***no support*** among social partners

Welding Fume Assistant



After 4 years >330 confident users

High, Medium or Low?

Dust exposure workers in grain transshipment

High, Medium or Low?

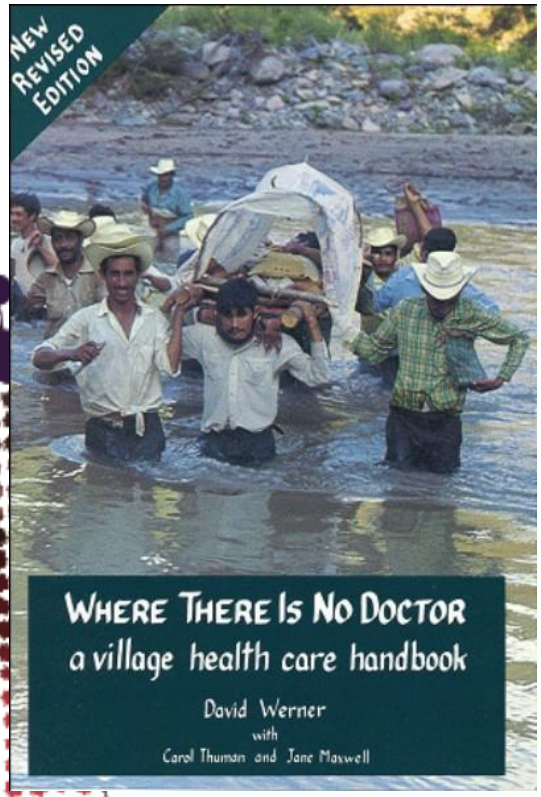
Dust exposure workers in pesticide formulation

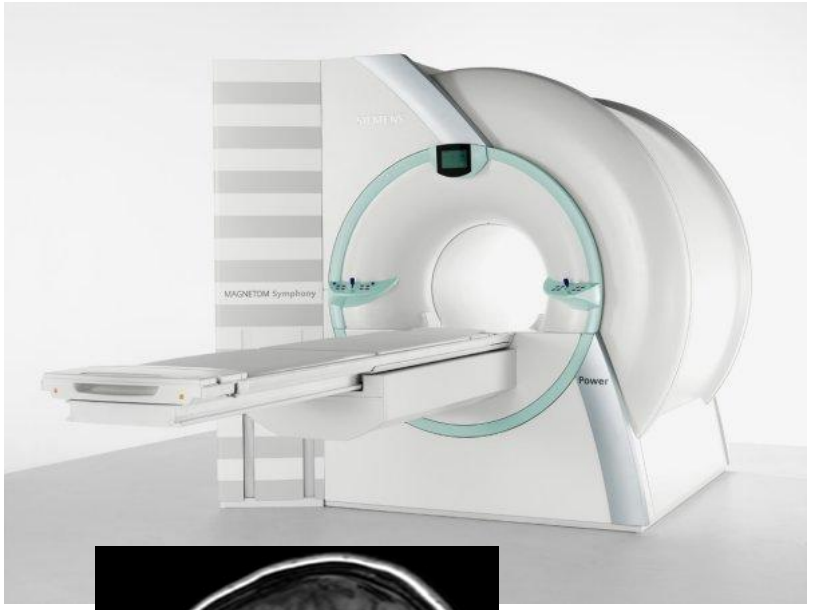
You didn’t need a tool for that, did you?

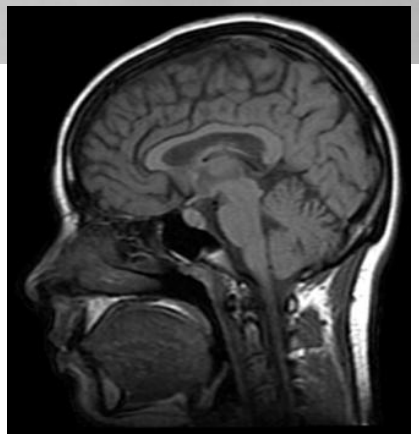
In conclusion

- Exposure assessment tools/models are needed and have a place
- Their performance (accuracy and precision) should be known before they are put on the market
- Mainly developed for desk top research for pre-registration purposes (e.g. REACH) and that is where they should be used for
- For post-registration purposes in workplaces current expert tools are not accurate and reliable enough to assess risk
- We do have measurement tools that can do that job in a (much more) valid and precise way

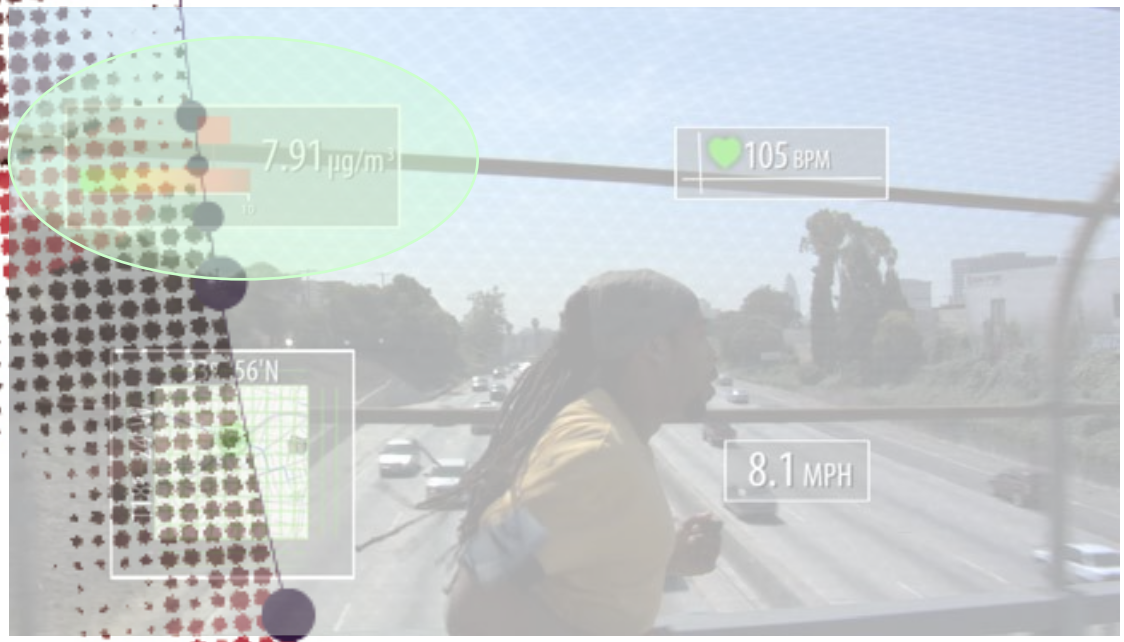
What would you prefer?







And the good news



We are moving away from a data poor past and present to a data rich future

Have a look at the video on YouTube of the Center for Embedded Networked Sensing (CENS) at UCLA

Be prepared that in a very near future a worker will compare your EASE / SM / ART / WFA estimate with his smart phone air pollution sensor outcome

And the good news

Because it is not only happening in the USA:

Draft Work Programme 2012 EU FP 7 Theme 6 Environment (24 March 2011):

ENV.2012.6.5-1 Developing community-based environmental monitoring and information systems using innovative and novel earth observation applications - FP7-ENV-2012-two-stage

New and innovative environmental monitoring and information capabilities can enable effective participation by citizens in environmental stewardship, based on broad stakeholder and user involvement in support of both community and policy priorities. The objective is to develop "citizens' observatories" using innovative earth observation technologies. These "citizens' observatories" should include community-based environmental monitoring, data collection, interpretation and information delivery systems. This will require the development of highly innovative monitoring technologies, (e.g. low-cost reliable micro-sensors), which can be embedded into large numbers of instruments, including highly portable devices.

We are talking about at least one project of 9 m€