Exposure Modelling

WINNIPEG Air Testing

Doug Wylie, CIH, ROH, CRSP, CRM

doug@winnipegairtesting.com

Significance of Chemical Exposures

I’m sure that we are all aware of the significance of chemical exposures

Perhaps “health” doesn’t get the attention of “safety”

Morbidity and mortality caused by exposures fly under the radar

99% of fatalities result from chemical agents (BOHS)

What is Needed to Improve Industrial Hygiene in Workplaces?

Why Assess Chemical Exposure?

Find previously unidentified high exposures.

Confirm and perhaps reduce PPE costs.

- Sometimes PPE is introduced in the absence of data.

The barrier to more assessments is the time/cost of sampling.

When to assess / When to sample

If a worker **is or may be exposed** to a hazardous substance, the employer must ensure that

(a) a walkthrough survey is conducted to assess the potential for overexposure

If the walkthrough survey reveals that a worker **may be at risk of overexposure** to an airborne contaminant, the employer must ensure that air sampling is conducted to assess the potential for overexposure.

Safety Data Sheets

Every company has 100's if not 1,000's of them

They all say "health effects this, health effects that"

Only a fraction are actually a problem

How do we identify the tigers from the kittens?

Walkthrough / Assessment by Company

You are a plant manager, a safety professional or HR

You have 400 SDSs, no technical background, limited budget

Companies have a chemical inventory

But they don't have an **exposure inventory**

Which is more useful?

Government Inspections

Infrequent

Consists of a “walkthrough”.

You have 400 SDSs and you get an improvement order for welding

What percentage of I/O’s for sampling reveal a high exposure?

Professional Judgement?

“Professional Judgement” or opinion (is that a system??)

Often swayed by false indicators

Odour (xylene)

Low TLV (isocyanates)

Serious health effects (benzene)

Infamy (asbestos)

Try and Predict the Exposure Band

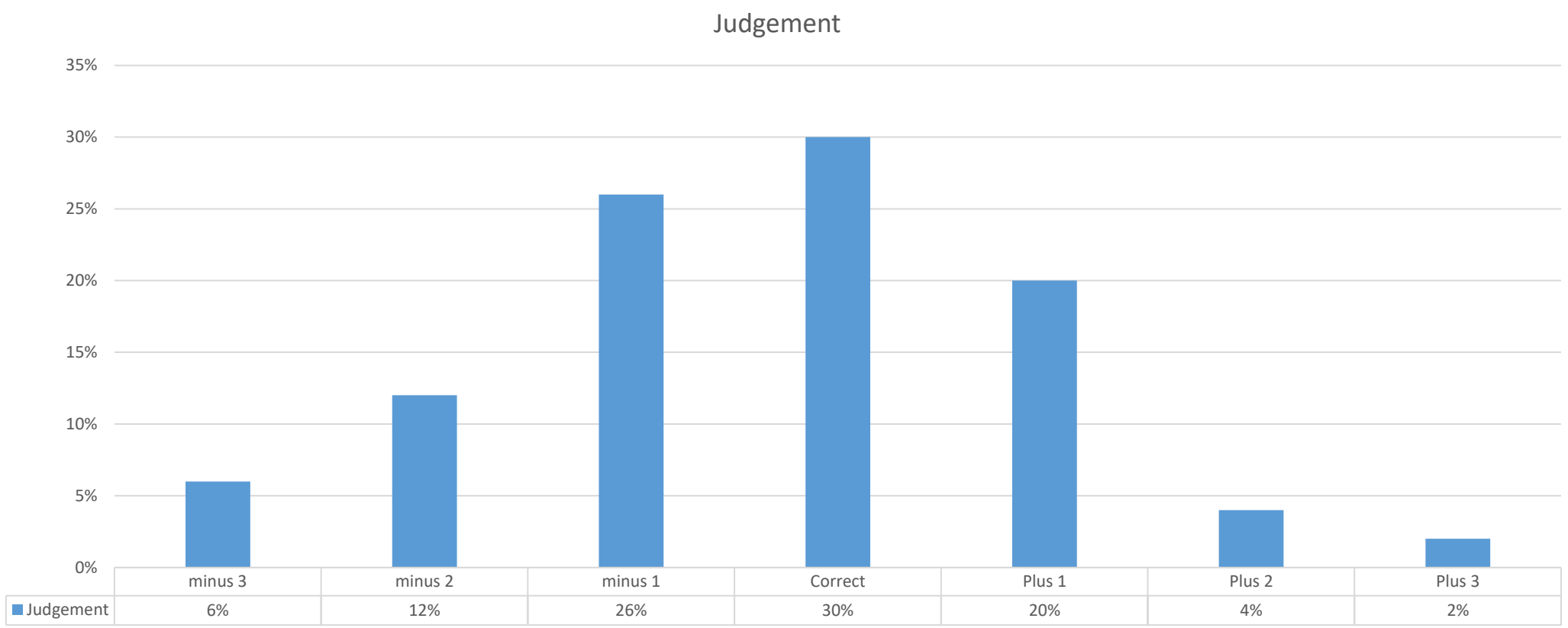
Exposure Rating	Recommended Action / Follow Up
< 1% of OEL	No Action
1 - 10% of OEL	General WHMIS Training
10 - 20% of OEL	+ Specific training on hazards of product
20 - 100% of OEL	+ periodic exposure monitoring
> 100% of OEL	+ respiratory, engineering or other controls
multiples of OEL	greater respiratory protection or process shutdown, introduce improved engineering controls

Want to assess this worker's exposure

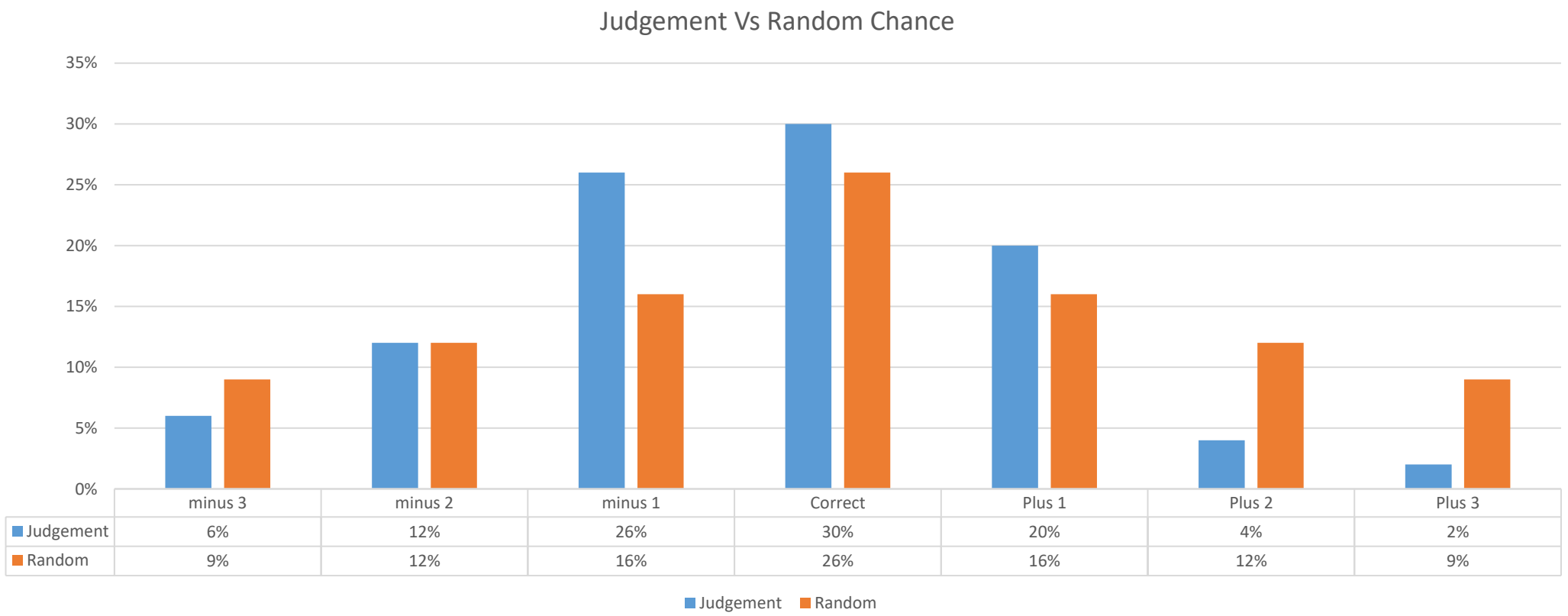
Spraying Butoxyethanol
2-4 hours / day
No respirator
General ventilation

What is the worker's exposure?
Do we all get the same answer?

IHs pick the right band 30% of the time Comments?

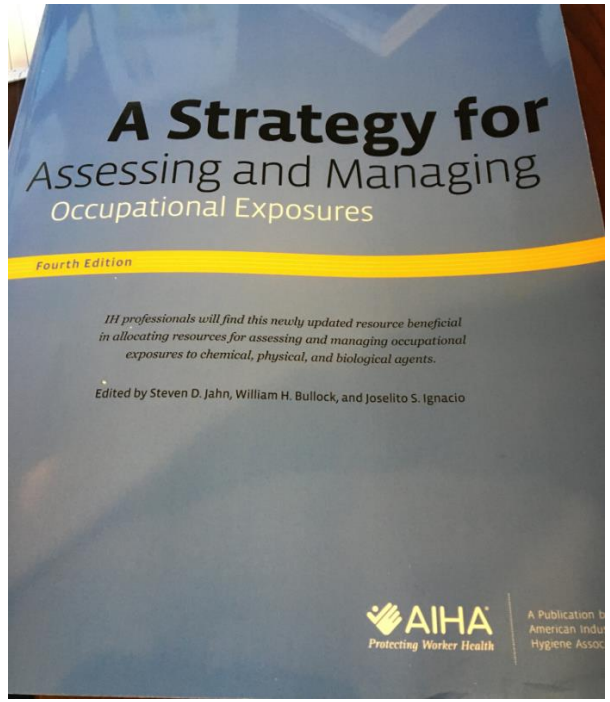


Not much better than random chance!



A strategy for Assessing and Managing Occupational Exposures (AIHA)

"Subjective assessment of exposures tend to be inaccurate and inconsistent with the exception of extreme scenarios. In fact, research has shown subjective qualitative exposure judgements tend to be no more accurate than random chance with a significant underestimation bias thus increasing risk to workers"



An argument could be make that random chance is

better than professional judgement

The old joke: Don't think. Guess. You'll be right more often.

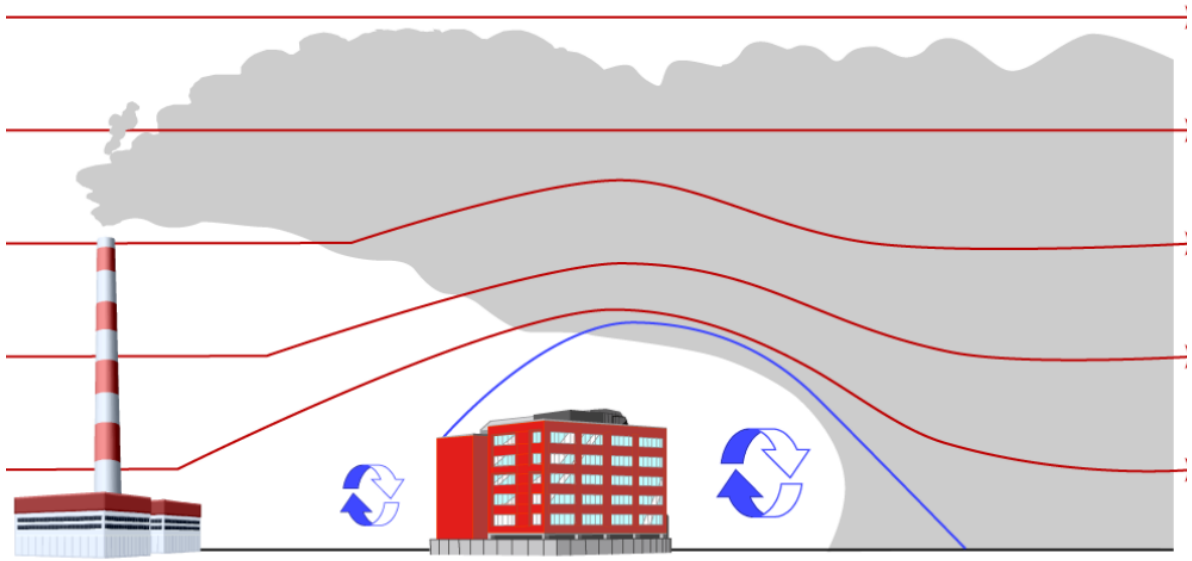
Surely there is better way

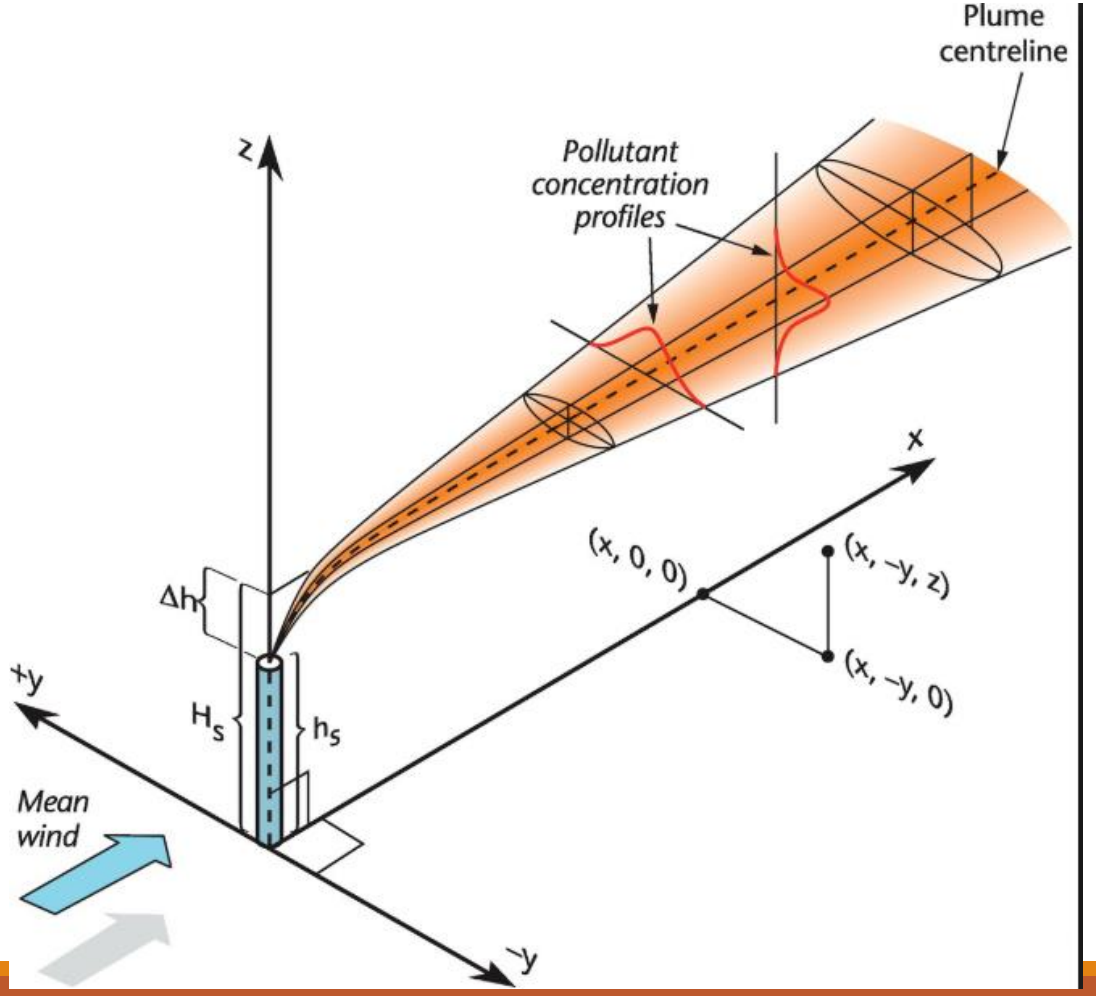
Would you like to have an assessment tool that …

1. Was a science-based approach?
2. Only took 2 of minutes to do?
3. Was back-checked against sampling data?
4. Proven better than what we are currently using?

Exposure Modelling

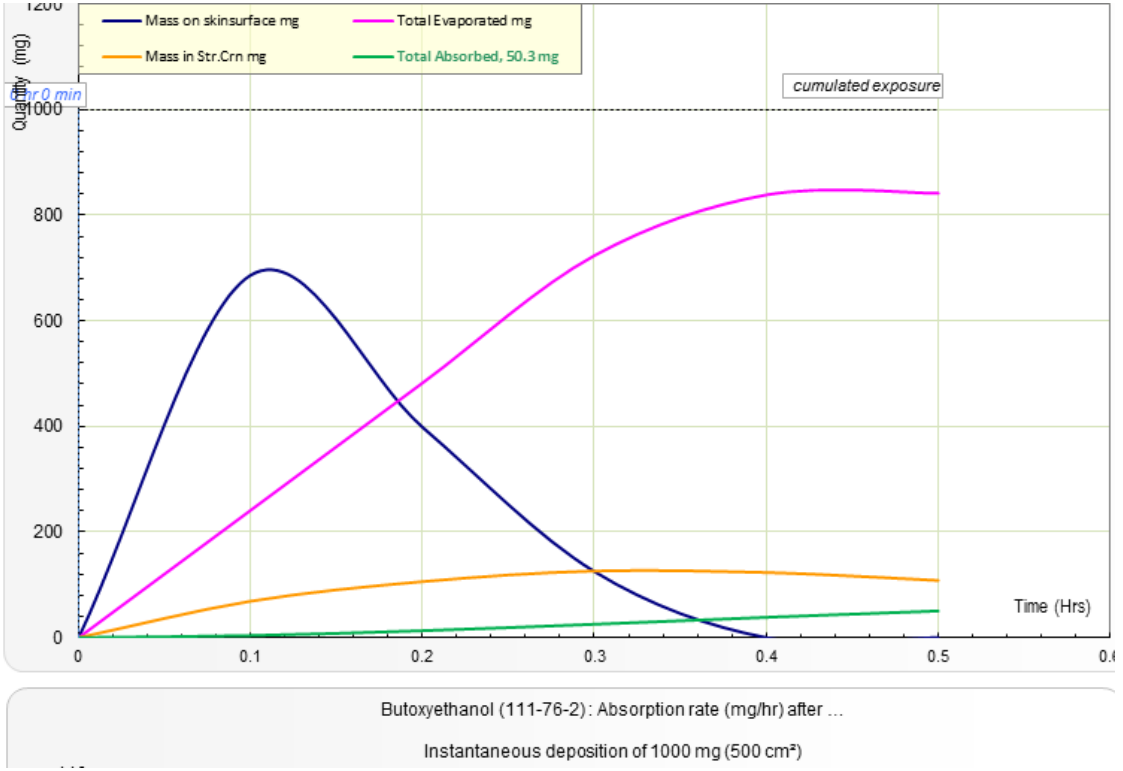
Modelling already used for other things





Exposure Models Exist for Dermal Exposure

Substance	Butoxyethanol (111-76-2)		
Deposition	Instantaneous		
Duration			
Tot. Deposition	1000 mg		
Fraction absorbed	5.0%		
Amount absorbed	50.289 mg		
	WATER	AIR	
Kp-lipids (vehicle water)	1.62E-3 cm/hr	2.61E+2 cm/hr	Kp-lipids (vehicle air)
Kp-keratins (vehicle water)	6.50E-5 cm/hr	1.05E+1 cm/hr	Kp-keratins (vehicle air)
Lag time stratum corneum	19.424 min		
Diffusivity of Stratum corneum	2.10E-6 cm²/hr	9.62E+1 cm/hr	Kp-stagnant air layer
Skin/Water partition ratio	1.6377	264057	Skin/Air partition ratio
	WATER	AIR	
Permeation coefficient water	1.69E-3 cm/hr	7.11E+1 cm/hr	Permeation coefficient air
5th percentile water	1.22E-3 cm/hr	6.47E+1 cm/hr	5th percentile air
95th percentile water	2.32E-3 cm/hr	7.66E+1 cm/hr	95th percentile air



Early Modelling Tool: EMKG-EXPO

1

Definition of volatility bands ?			
Band	At normal temperature (~20°C)	Operating temp. (o.t.	Vapour pressure (kPa at o.t.)
Low	boiling point above 150°C	b.p. ≥ 5 x o.t. + 50	< 0.5
Medium	boiling point between 50 and 150°C	other cases	0.5 - 25
High	boiling point below 50°C	b.p. ≤ 2 x o.t. + 10	> 25

Alternative input of ?	
boiling point [°C] **and** operating temperature [°C]	
input b.p.	*input o.t.*

2

Scale of use bands ?	
Band	Description
Small	millilitres up to 1 litre for liquids
Medium	litres (batch sizes between 1 and 1000 litres for liquids)
Large	cubic metres (batch sizes of greater than 1 m^3 for liquids)

Short term exposure ?	
Activity < 15 min. during a full 8 h shift?	
Yes	*No*

Applications on surfaces > 1m² ?	
e.g. painting, applying adhesives etc. and more than 1 litre product used per shift!	
Yes	*No*

3

Control strategies ?		
Control Approac	Type	Description
1	General ventilation	Good general ventilation and good work practice
2	Engineering control	Local exhaust ventilation (e.g. single point extract, partial enclosure, not complete containment) and good work practice
3	Containment	Enclosed, but small breaches may be acceptable. Good work practice.

Exposure potential bands (EP)			
Solids – EP band	Use band	Volatility band	Description
1	Small	Low	Millilitres of low volatility liquid
2	Small	Medium or High	Millilitres of medium / high volatility liquid, litres / cubic metres of low volatility liquid
	Medium or Large	Low	
3	Large	Medium	Cubic metres of medium volatility liquid, litres of medium / high volatility liquid
	Medium	Medium or High	
			Cubic metres of high

Predicted exposure ranges: Liquids				
Control Approach	Predicted exposure level for vapour, ppm			
	Solids EP Band 1	Solids EP Band 2	Solids EP Band 3	Solids EP Band 4
	(mL of low VP liquid)	(mL of med. / high VP liquid or L / m³ of low VP liquid)	(m³ of med. VP liquid or L of med. / high VP liquid)	(m³ of high VP liquid)
1	< 5	5 - 50	50 - 500	> 500
2	< 0.5	0.5 - 5	5 - 50	5 - 500
3	< 0.05	0.05 - 0.5	0.5 - 5	0.5 - 5

MEK (Boiling point = 79 deg C)

ACGIH TLV = 200 ppm

Easy to use

EMKG prediction = 5 – 500 ppm

So between 3% - 250% of the TLV??

Technically that is probably “accurate” but not “accurate” enough to be much help

What We Want in an Exposure Model.

Accurate (at least better than professional judgment)

Easy to Use / Understand

Consistent predictions

Uses terms and units we know

Fits in with your IH program and legislation

WATSIN: a Chemical Exposure Algorithm

PROMPTS US TO CONSIDER THE IMPORTANT THINGS

COLLECTS THE CORRECT INFORMATION

WEIGHS THE INFORMATION CORRECTLY

WEIGHS THE INFORMATION CONSISTENTLY

WATSIN (asks a modest number of questions)

Duration

Worker Proximity

Process (spraying, heating, etc.)

Ventilation/Controls

Respirators

Occupational Exposure Limit

Emission factor (vapour pressure, dustiness)

Obviously Duration is a factor

DURATION OF ACTIVITY

The duration of the activity plays a role in the magnitude of the exposure.

Select one of the choices below that best fits your scenario: *

- ○ Exposure occurs less than 1 day / month or less than 5 minutes per day
- ○ Exposure occurs at least 1 day per month and lasts between 5 minutes and 1 hour / day
- ○ Exposure occurs 1 – 2 hours / day
- ○ Exposure occurs 2 – 4 hours / day
- ○ Exposure occurs 4 – 8 hours / day
- ○ Exposures occur more than 8 hours per day or more than 40 hours / week

Previous Next

Worker Proximity – Pick the Best Option

PROXIMITY

How close a worker is to any fugitive emission is a significant metric of the magnitude of the worker's exposure.

Worker is Nearby | Arm's length | Directly in Emission

Select one of the choices below that best fits your scenario. *

- ○ Intermittently nearby
- ○ Worker is consistently nearby
- ○ Worker at arm's length
- ○ Worker is directly in emission

Previous Next

Nature of Process (both isocyanates)

NATURE OF PROCESS

Some specifics of the process can affect the exposure. For example, spraying a product into the air will increase the concentration. On the other hand, raising the temperature will raise the vapour pressure and accelerate evaporation. This section tries to take these specifics into account.

Select the choice that best describes your situation. *

- ○ Default
- ○ Vigorous mixing, pouring of liquids, spray bottles
- ○ Spraying (spray cans or spray painting)
- ○ Spread on mechanical rollers (printing press)
- ○ Temperature process is warm (+ 10) deg C
- ○ Process is too hot to touch

Previous Next

Controls (primarily ventilation)

CONTROLS

Potential exposures can be reduced by controls - depending on how efficient those controls are.

Select the choice that best describes your situation. *

- Closed system with no release in work area (e.g., closed piping, sealed drums)
- Effective engineering controls in place (e.g., local exhaust systems with good capture of emissions)
- Moderately effective local exhaust with partial capture
- Open system with effective general ventilation in place to contain and/or remove airborne contaminants from work area (e.g., 6 - 12 air changes per hour of general ventilation)
- Open system with combination of general ventilation and administrative controls in place to control exposure (e.g., 3 - 6 air changes per hour of general ventilation)
- Open system with administrative controls but no or ineffective engineering controls (e.g., relies almost exclusively on administrative controls)
- Open system with no administrative or engineering controls in place (basically no controls in place)

Previous Submit

Respirators

RESPIRATORY PROTECTION

This page is intended to correct for the use of respiratory protection (if any).

Respiratory Protection *

- ○ No respirator
- ○ Half face respirator
- ○ Loose fitting respirator
- ○ Full face respirator

Previous Next

Vapour Hazard Ratio

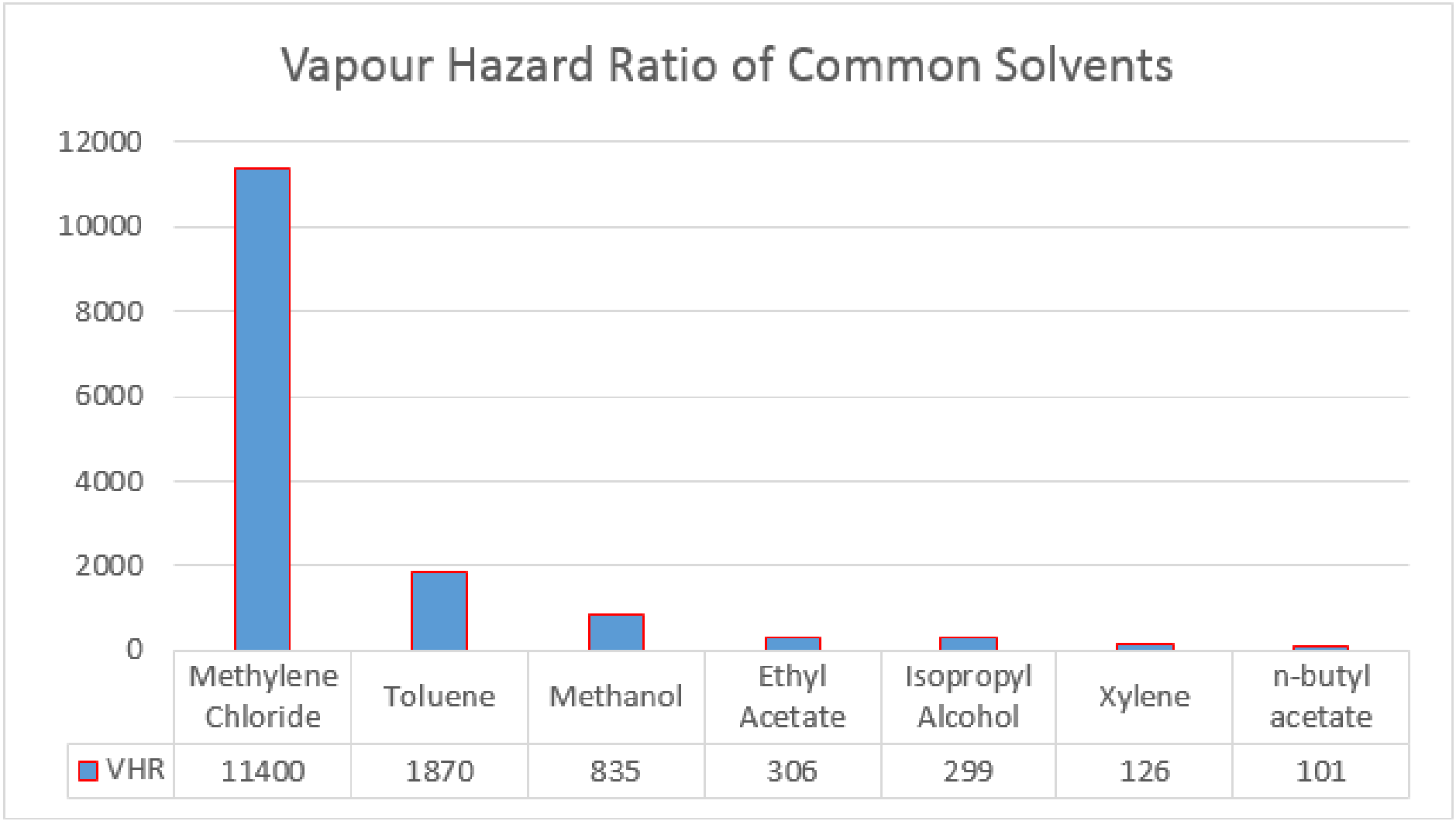
Combines Volatility and Occupational Exposure Limit

Vapour pressure / OEL = Vapour Hazard Ratio

Gives you a number of how likely the exposure is to be above the OEL

Depends on conditions of Use (more on this later)

VHR is most important metric of solvents



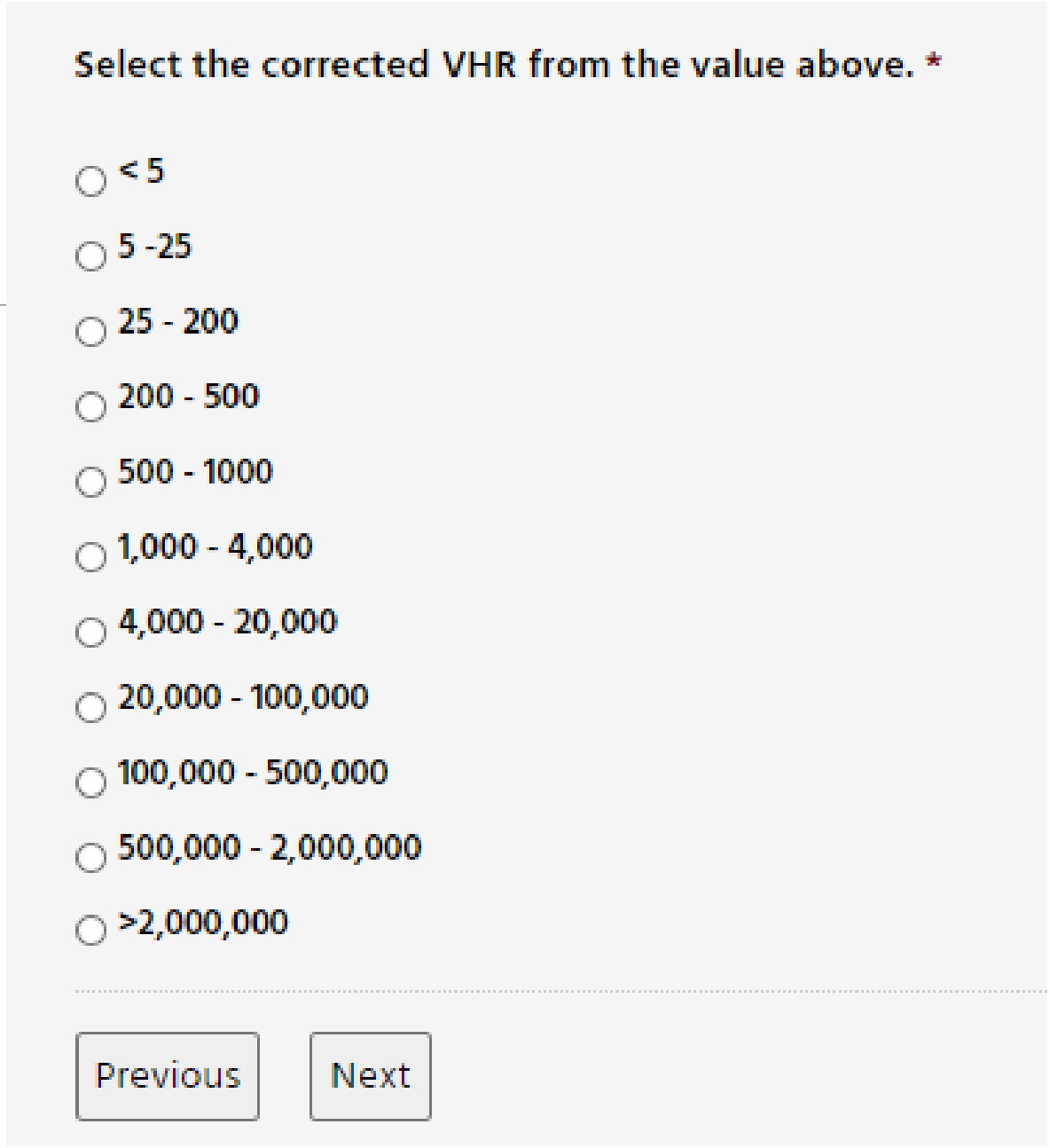
Searchable Table of VHRs

Search:

CAS #	Name	TLV (ppm)	VHR
106-94-5	1-Bromopropane	0.1	1460000
75-15-0	Carbon disulfide	1	472000
71-43-2	Benzene	0.5	249000
56-23-5	Carbon tetrachloride	5	30300
67-66-3	Chloroform	10	25900
50-00-0	formaldehyde	0.1	17105
822-06-0	hexamethylene diisocyanate (HDI)	0.005 ppm	13158
75-09-2	Methylene chloride	50	11400

Select the proper range

For mixtures, use highest VHR of all of the ingredients



Enter your data and click submit

Duration: Exposure occurs 4 – 8 hours / day

Proximity: Worker at arm's length

Vapour Hazard Ratio: 1,000 - 4,000

Nature of Process: Spraying (aerosols or spray painting)

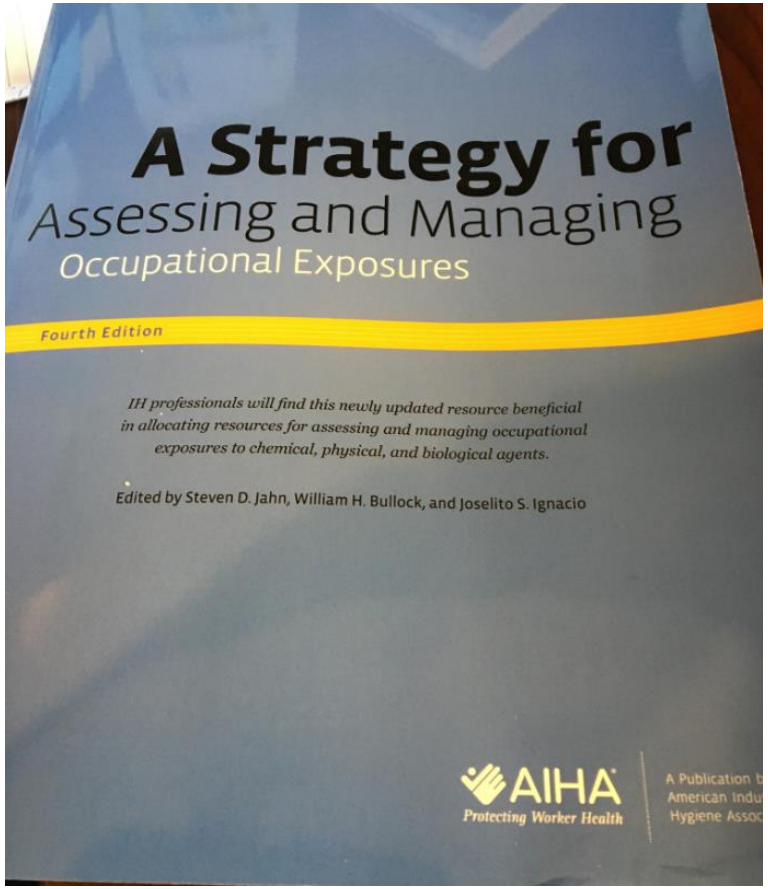
Controls: Enclosed and ventilated booth (spray booth)

Estimated exposure is	Action to take
<1 % of the OEL	No Action Recommended
1 - 10% of OEL	General WHMIS Training
10 - 20% of OEL	plus specific training on hazards of products
20 - 100% of OEL	plus periodic exposure monitoring
> 100% of OEL	plus respiratory, engineering or other controls
Multiples of OEL	greater respiratory protection, improved controls or process shutdown

DO Algorithms WORK?

"Algorithms consider critical and consistent inputs and are consistently better at making accurate judgements. Algorithms may not be 100% accurate but are close enough to be informative and ensure limited resources are used efficiently"

(A Strategy for Assessing and Managing Occupational Exposures, AIHA)



Winnipeg Air Testing

Been in use for a couple of years

Use it as a screen for projects

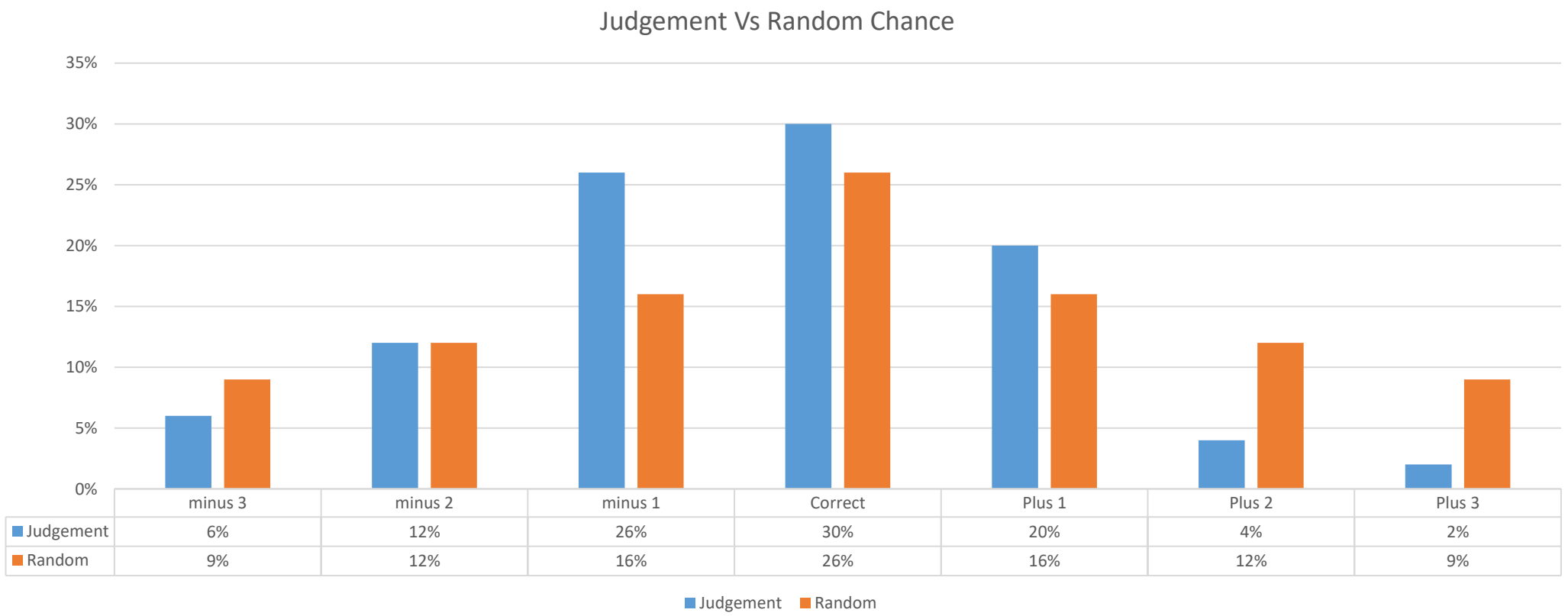
Also compare predictions with actual sampling data

Developing a database of predictions vs sampling results

This has helped us develop and refine the tool (back checked against actual sampling data)

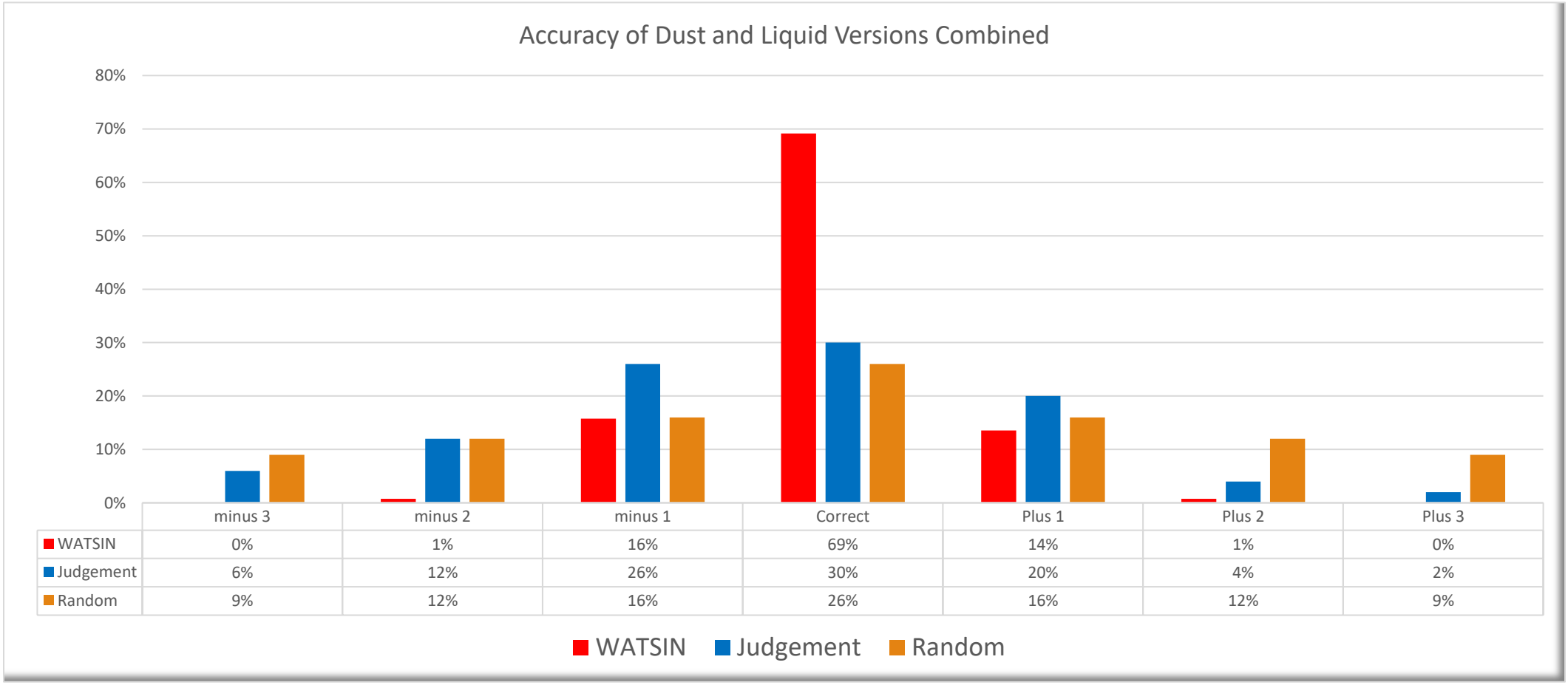
Compare Predicted / Measured Exposure

Professional judgement is currently our standard assessment approach



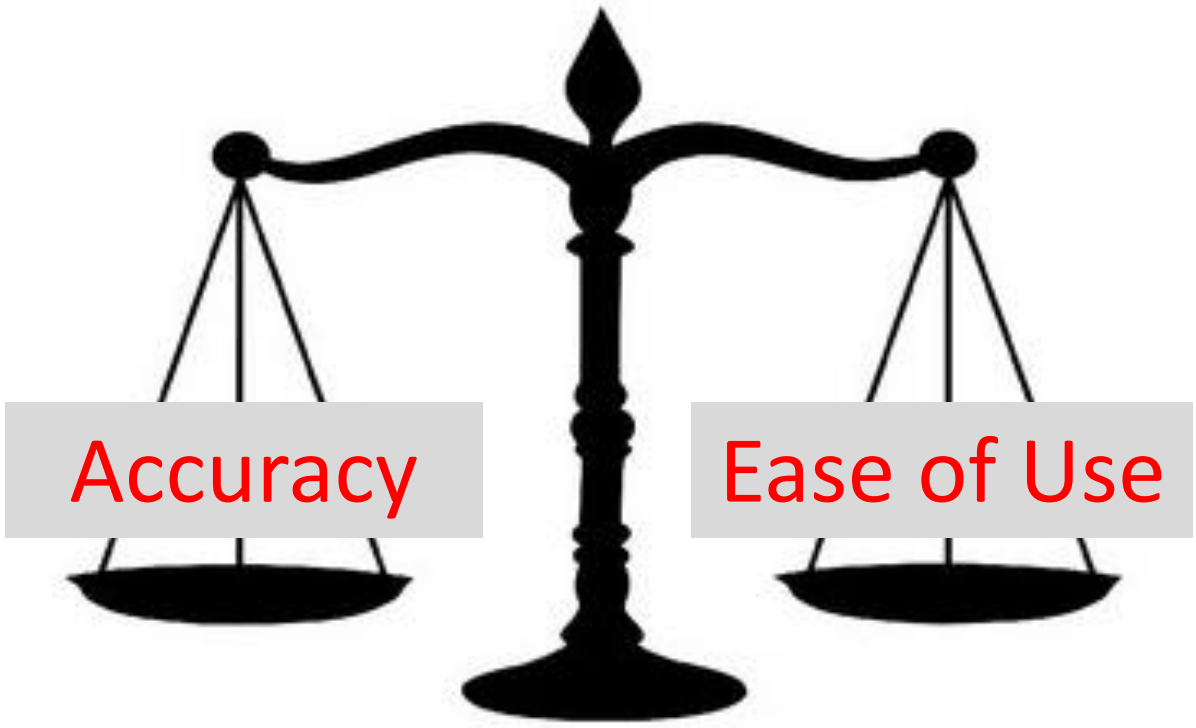
	minus 3	minus 2	minus 1	Correct	Plus 1	Plus 2	Plus 3
Judgement	6%	12%	26%	30%	20%	4%	2%
Random	9%	12%	16%	26%	16%	12%	9%

Not Perfect but better than judgement

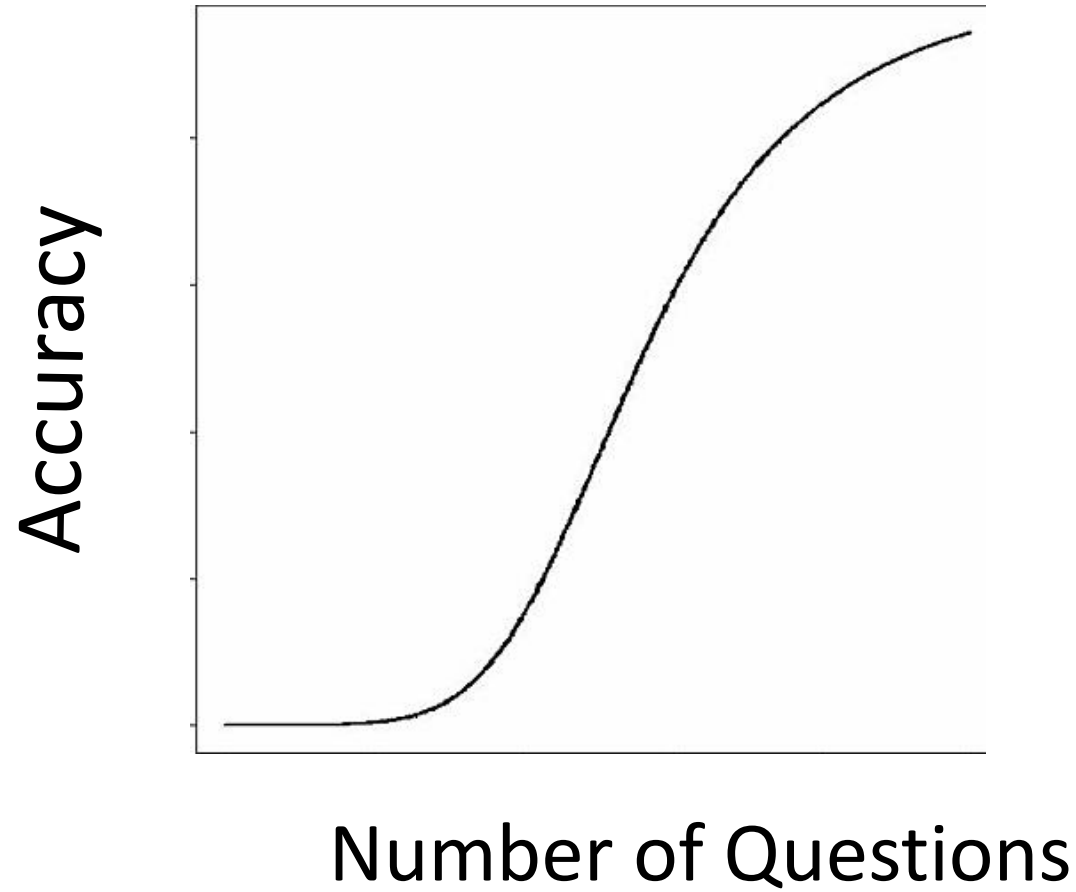


	minus 3	minus 2	minus 1	Correct	Plus 1	Plus 2	Plus 3
WATSIN	0%	1%	16%	69%	14%	1%	0%
Judgement	6%	12%	26%	30%	20%	4%	2%
Random	9%	12%	16%	26%	16%	12%	9%

Strike a Balance



Need a number of questions but perhaps limited improvement after a point.



WATSIN predictions in a manufacturing plant

Chemical	Description of Process	Predicted Exposure Band	Recommendation
	Dust		
Manganese	Welding	20 – 100%	Air Sampling
	Liquids		
#43 – Klene Sol	Wiping panels	1-10%	
#47 Scotch Grip	Wiping panels	20-100%	Air Sampling
MDI	Spraying	< 1%	
#51 Equip cleaner	Wiping parts	20-100%	Air Sampling
Hydrofluoric and sulfuric acids	Dipping parts in acid	20-100%	Air Sampling
Toluene	Wiping floor	1-10%	No resp needed?
Isopropanol	Wiping panel	1-10%	No resp needed?
MDI	Gluing around windows	<1%	
Plexus MA 1020	Adhesive	1-10%	
3M Fastbond	Isopropanol	10-20%	

Sampling Results VS Predictions

Chemical	Description of Process	Predicted Exposure Band	Sampling Results
Dust			
Manganese	Welding	20 – 100%	29% (1)
Liquids			
#43 – Klene Sol	Wiping panels	1-10%	37% (2)
#47 Scotch Grip	Wiping panels	1-10%	4% (3)
MDI	Spraying	< 1%	
#51 Equip cleaner	Wiping parts	20-100%	90%
Hydrofluoric and sulfuric acids	Dipping parts in acid	20-100%	97%
Toluene	Wiping floor	1-10%	4%
Isopropanol	Wiping panel	1-10%	
MDI	Gluing around windows	<1%	
Plexus MA 1020	Adhesive	1-10%	
3M Fastbond	Isopropanol	10-20%	

Breaking leaded glass with a hammer

Does it all day

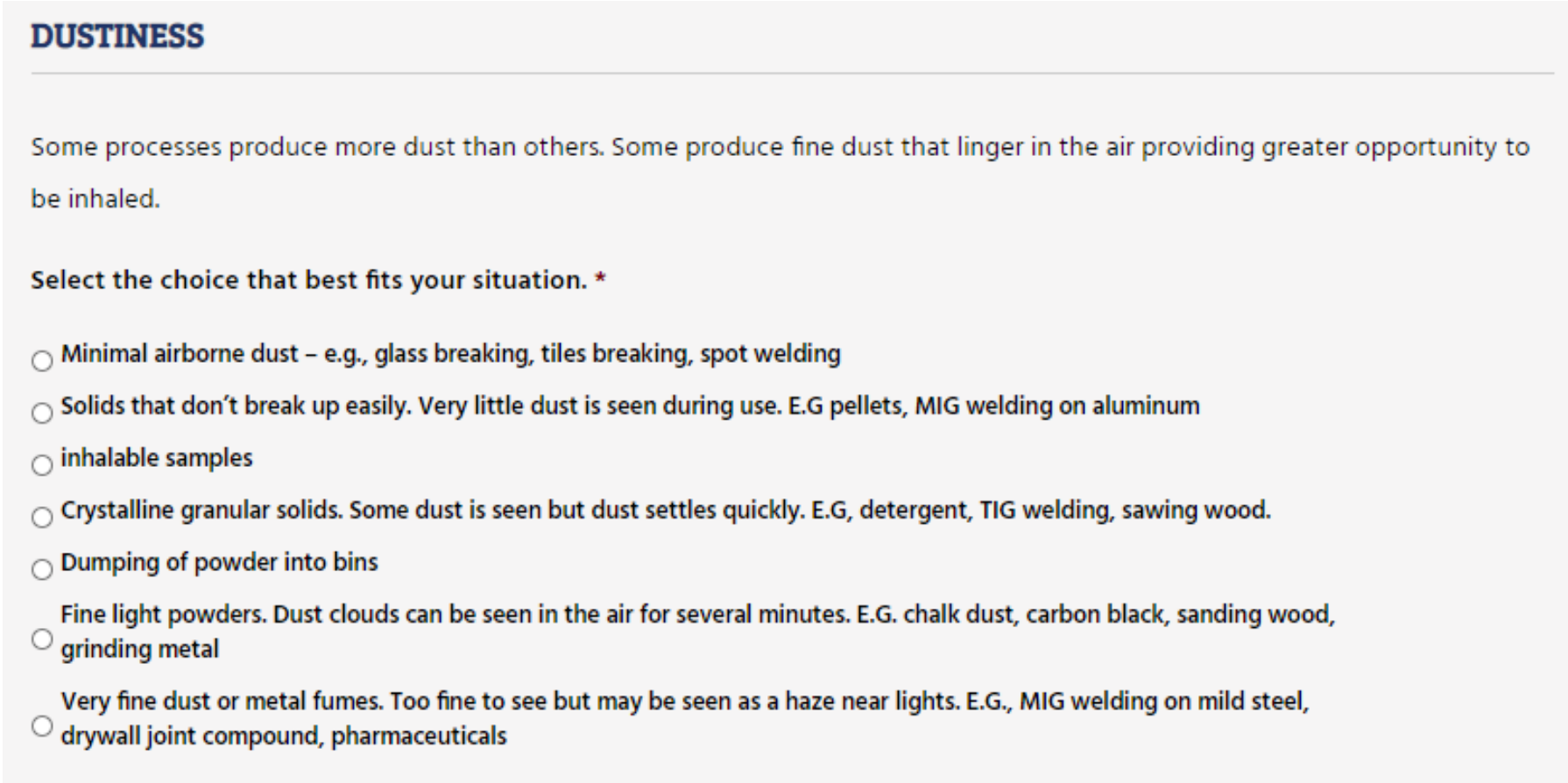
No respirator

Breaks into shards

No respirator

General ventilation

TLV = 0.05 mg/m3



DUSTINESS

Some processes produce more dust than others. Some produce fine dust that linger in the air providing greater opportunity to be inhaled.

Select the choice that best fits your situation. *

- ○ Minimal airborne dust – e.g., glass breaking, tiles breaking, spot welding
- ○ Solids that don't break up easily. Very little dust is seen during use. E.G pellets, MIG welding on aluminum
- ○ inhalable samples
- ○ Crystalline granular solids. Some dust is seen but dust settles quickly. E.G, detergent, TIG welding, sawing wood.
- ○ Dumping of powder into bins
- ○ Fine light powders. Dust clouds can be seen in the air for several minutes. E.G. chalk dust, carbon black, sanding wood, grinding metal
- ○ Very fine dust or metal fumes. Too fine to see but may be seen as a haze near lights. E.G., MIG welding on mild steel, drywall joint compound, pharmaceuticals

DUST EXPOSURE CALCULATOR

Duration: Exposure occurs 4 – 8 hours / day

Proximity: Worker at arm's length

Dustiness: Minimal airborne dust – e.g., glass breaking, tiles breaking, spot welding

OEL: 0.01 – 0.09

Respiratory Protection: No respirator

Controls: Open system with moderate general ventilation in place (e.g., 3 - 6 air changes per hour of general ventilation)

Estimated exposure is	Action to take
<1 % of the OEL	No Action Recommended
1 - 10% of OEL	General WHMIS Training
10 - 20% of OEL	**plus specific training on hazards of products**
20 - 100% of OEL	plus periodic exposure monitoring
> 100% of OEL	plus respiratory, engineering or other controls
Multiples of OEL	greater respiratory protection, improved controls or process shutdown

Exposure Modelling

Exposure assessment with no sampling costs

Only takes a couple of minutes to do

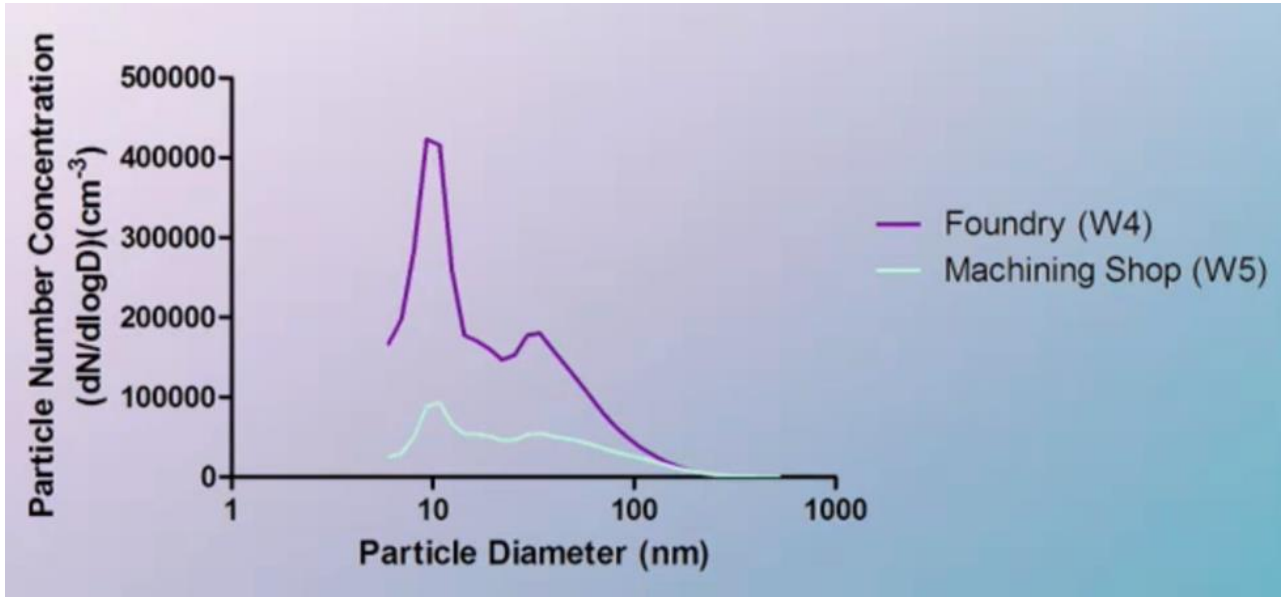
Proven better than what we are currently using

Impartial

Consistent

Limitations

- Doesn’t do spills or chemical reactions
- Doesn’t do confined spaces
- Doesn’t do fibres
- Doesn’t do downwind
- Doesn’t do foundries



Like any model

Garbage in = garbage out Needs some judgement

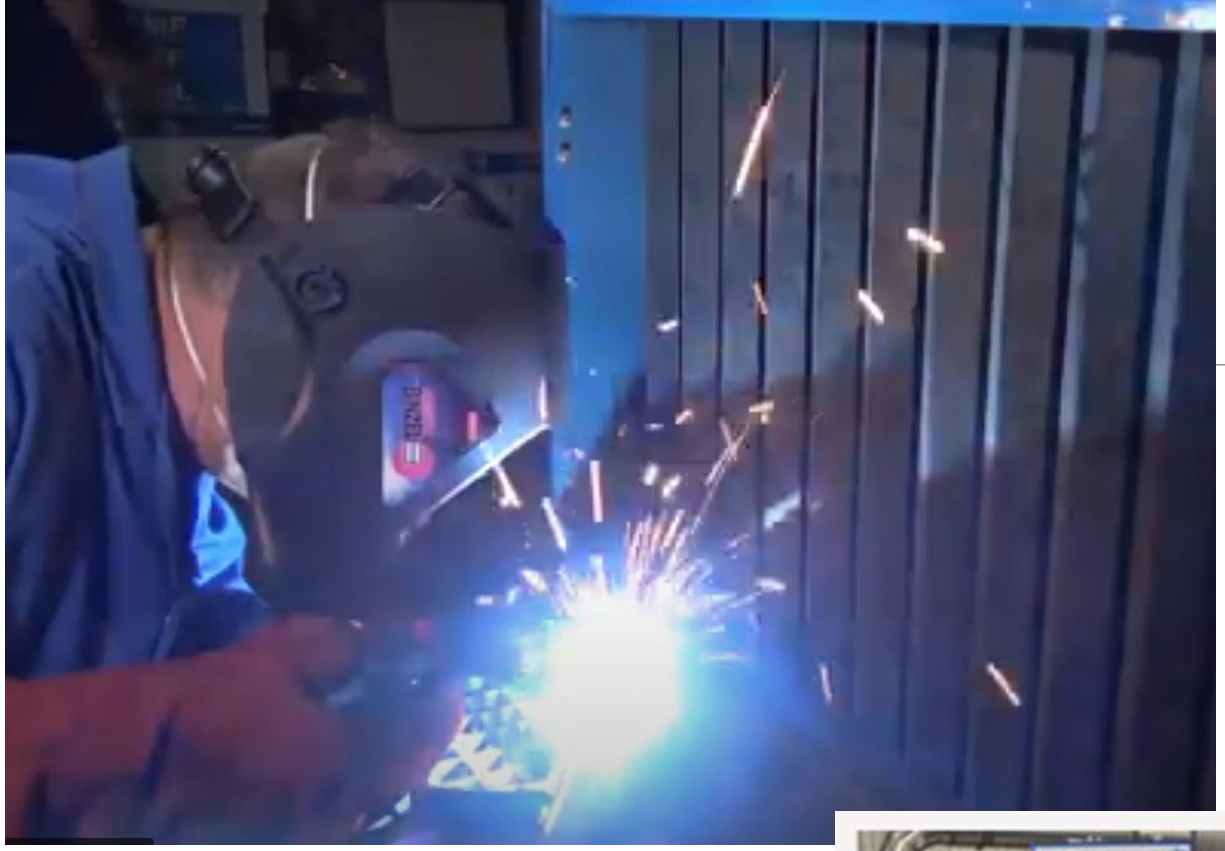
Tried to give explanations and examples

Can run similar variations

- good local exhaust vs moderately effective local exhaust

Not perfect

Perhaps need a WATSIN-*PRO* version for IHs?



Hopefully, everyone would recognize this as directly in emission

Do IHs and non-IHs give the same answers?

Parameter	Same/Judgement
Duration	Same
Worker Position	Judgement (maybe)
VHR	Same
Respirators	Same
Controls	Judgement
Process	Same

Non-IHs using WATSIN give better predictions than IHs using professional judgement
IHs give better predictions than non-IH when both are using WATSIN

Misuse of WATSIN?

Entering the OEL rather than the VHR.

Difference between **owning** local exhaust and **using** local exhaust

Estimating downwind exposure because houses were “nearby”

Worker is Nearby

WATSIN vs Other Assessment Options

Good	Exposure Calculator using Mathematical Algorithm
Good	Typical Exposures from Published Studies
Acceptable	Estimate of exposure by a Qualified Person
Poor	Information on Safety Data Sheets

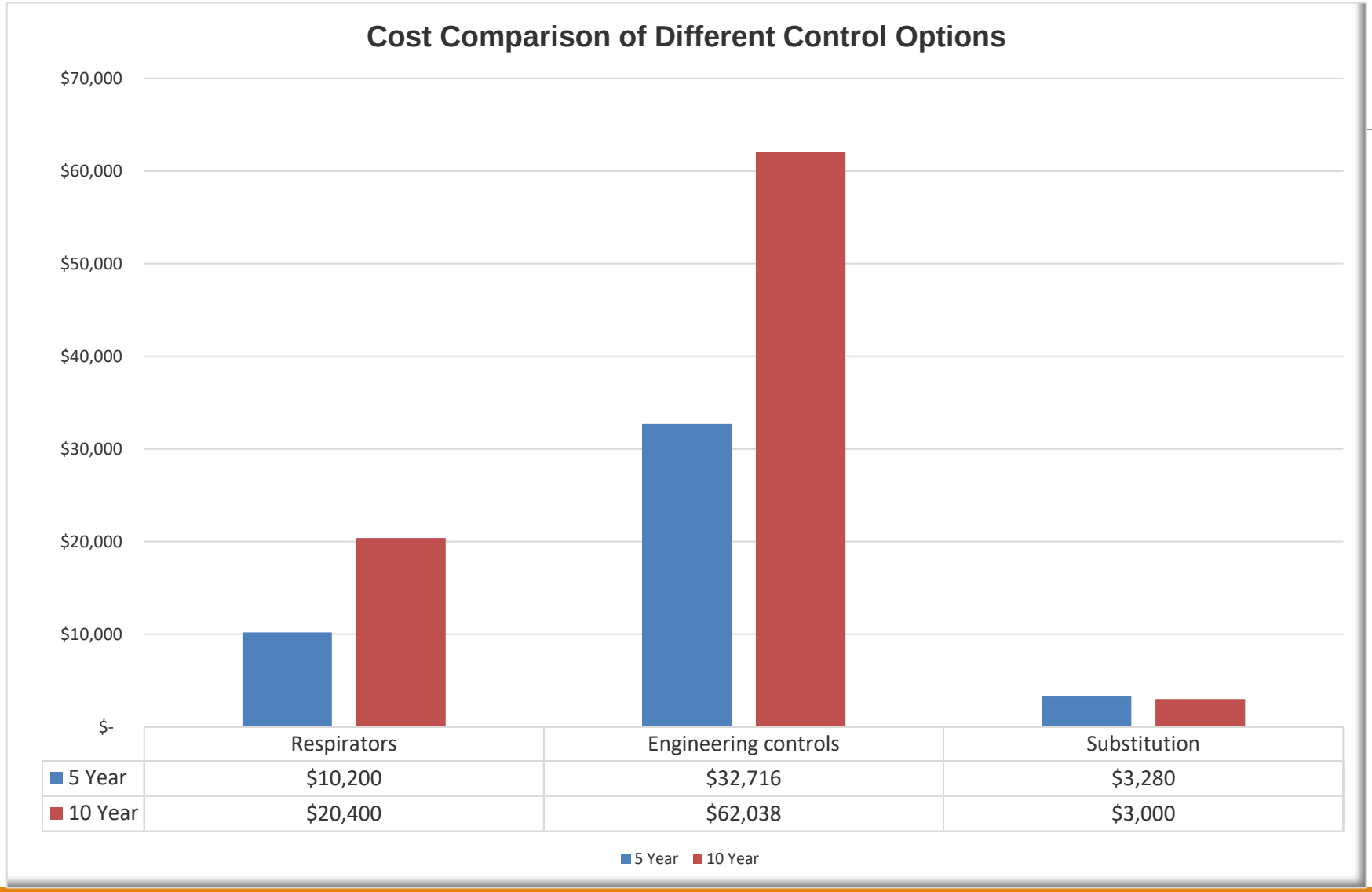
Great for Substitution

Bringing in a new product? Would you like to know the exposure before you use it? Would management be more open to substitution with a reliable prediction for the new product?

What would the exposure be if you switched to from toluene to MEK?

We can look at a new products and get a prediction in 2 minutes

Cost of Controls Calculator helps prompt substitution



	Respirators	Engineering controls	Substitution
5 Year	$10,200	$32,716	$3,280
10 Year	$20,400	$62,038	$3,000

Calculates the cost of respirators and filters

Calculates the cost of buying and operating ventilation controls

Calculates the cost of a switching to a safer product

Compares costs in a graph

Predict Exposure with Improved Controls

Manganese Concentration	263 ug/m^3	13.3 ug/m^3
Ventilation Control	Canopy Ventilation System 	Welding Fume Extraction Arm 
PPE:	½ Face Respirator with P100 Particulate Filters	
Exposure with Respirator	> 100%	1 – 10%
2018 ACGIH TLV: 20 µg/m^3		

Possible Future Improvements

Background levels

- Sounds good but how good or accurate is the opinion of background level?

Correction for surface area

- Some models use volume but for liquid evaporation, surface area seems like a better metric.

Professional Judgement

- A catch all correction for judgement that may allow for other factors (can always use the default option).

Exposure Modelling is Here

Find hidden overexposures

Show respirators not needed

Justify Sampling (or not sampling)

Makes substitution easier

Better focus resources

Better IH program for less time and sampling costs

Summary

After decades and generations of practice, walkthroughs and subjective assessments are not a reliable means of assessing chemical exposure and will continue to be unreliable.

Science-based algorithms are a more accurate and more consistent approach and will only get better as they are refined and improved.