



Advancing Worker Health Protection

9th - 13th June | Aviva Stadium | Dublin

## 5. Processing measurement outcomes

(AIHA 4<sup>th</sup> edition, EN689 clause 5.1 ).

NVvA 2024 – PBC Woudschoten 9-4-2024

IOHA 2024 – PDC-150 Dublin 9-6-2024

Peter van Balen

Robbert Emonds

Theo Scheffers



# Exposure profiling

## Purple is processing measurement outcomes

1. Identify the SEG to profile.
2. Stratify the select workers and time periods within the SEG selected for study.
3. Measure the exposures of the randomly selected workers and the randomly selected time periods.
4. Calculate the descriptive statistics.
5. Determine if the data fits a lognormal and/or normal distribution.
6. Calculate the parametric statistics.
7. Make a decision on acceptability of the exposure profile.
8. Refine the SEG if necessary.

Backgrounds, details and consequences next Thursday in Theo's presentation; session 11B Room 1872 (Exposure assessment).

Reference period	Measuring range	Relative expanded uncertainty
short-term (for example, 15 min)	0,5 times to 2 times limit value	$\leq 50 \%$
long-term	0,1 times to $< 0,5$ times limit value	$\leq 50 \%$
long-term	0,5 times to 2 times limit value	$\leq 30 \%$

# Warning: decimal sign (in LoQ notation <...)

Explanation

IH-Aligner

Version: 9.3.5-l

Sampled substance

Heptane (Paul Hewett) [AIHA-2015 4e edition] (TLV TWA US)

12-06-2024

OELV

288.00

nm

Date	Person / Group / ID	Measured concentration in ppm (< sign before value in case of concentration below LoQ)	Total Sampling Duration (TSD) (minutes). Default 480	Worker's Exposure time t (minutes). Default 480	SEG Daily exposure duration or Workers Exposure time (t) (minutes)	Workers Concentration C(Rp) aligned to the OELV Reference period (Rp): - red cell > OELV, - yellow cell < LoQ.	Workers Concentration C(Rp) aligned to the OELV Reference period (Rp): - red cell > OELV, - yellow cell < LoQ.
01-01-2021	worker1	124,000	480	480	480,00	124,00	
01-02-2021	worker1	63,000	480	480	480,00	63,00	
01-03-2021	worker1	274,000			480,00	274,00	
01-04-2021	worker2	44,000			480,00	44,00	
01-05-2021	worker2	<8.0			480,00	Non numeric input	
01-06-2021	worker2	23,000			480,00	23,00	

Adjust the notation with the correct separator for decimals in your version of Excel. In this case use a comma.

			(< sign before value in case of concentration below LoQ)				OELV, < LoQ.	- red - yellow
1	01-01-2021	worker1	124,000	480	480	480,00	124,00	
2	01-02-2021	worker1	63,000	480	480	480,00	63,00	
3	01-03-2021	worker1	274,000	480	480	480,00	274,00	
4	01-04-2021	worker2	44,000	480	480	480,00	44,00	
5	01-05-2021	worker2	<8.0	480	480	480,00	Non numeric input	
6	01-06-2021	worker2	23,000	480	480	480,00	23,00	

Adjust the notation with the correct separator for decimals in your version of Excel. In this case use a comma.



# Example: measurements of n-heptane

(AIHA 2015 4<sup>th</sup> edition)

- 6 workers and 3 samples/worker

- OELV:

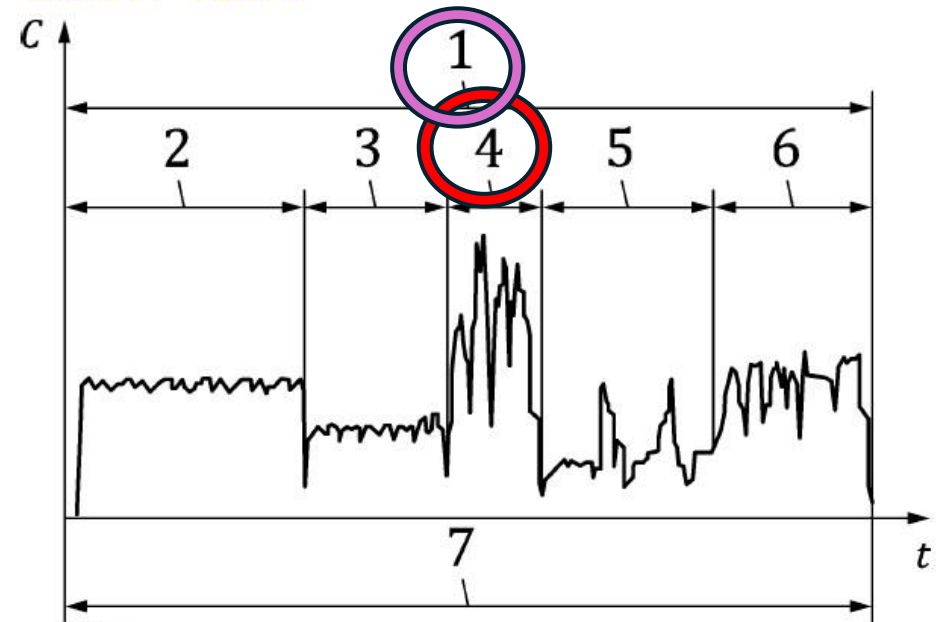
- NL:

- $TWA_{8h}$ : 288 ppm (1200 mg/m<sup>3</sup>) => 1
    - $TWA_{15min}$ : 384 ppm (1600 mg/m<sup>3</sup>) => 4

- US (ACGIH)

- TLV-TWA: 400 ppm (1640 mg/m<sup>3</sup>) => 1
    - TLV-STEL: 500 ppm (2050 mg/m<sup>3</sup>) => 4

Multiple exposure profiles during the whole shift.



Key

$C$  exposure concentration

$t$  time

1 TSD = WS

2 TSD<sub>i=2-6</sub>

7 WS

Figure D.4

Explanation	IH-Aligner				Version: 9.3.4-I	Person / Group / ID	C <sub>s</sub> OELV?	C <sub>t</sub> +Extended Uncertaintyf(OELV)? - n<=3: 10% OELV - n=4: 15% OELV - n=5: 20% OELV	C <sub>t</sub> +Extended Uncertaintys/OELV?	Result Preliminary test N=3-5
Sampled substance	Heptane (Paul Hewett) [AIHA-2015 4e edition] (TLV TWA US)				04-06-2024					
OELV	400,00	mg/m <sup>3</sup>								
Reference period OELV (Rp)	8 hours	480	minutes							
Daily Exposure duration SEG (if appropriate, change the default 480)	480			Personal Air Sampling method	sorbent tube, active with pump					
				Relative expanded Uncertainty (%) EN482 (2021) 6.1. g formula (4) & Annex B ISO-IEC Guide98-3 (2008)	0%					

at most 30% at .1<OELV/TDS-c<2 50% outside this range										
	Date	Person / Group / ID	Measured concentration in mg/m <sup>3</sup> (< sign before value in case of concentration below LoQ)	Total Sampling (TSD) (min) Default 480	Exposure time t (minutes). Default 480	SEG Daily exposure duration or Workers Exposure time (t) (minutes)	Workers Concentration C aligned to the O Reference period (red cell > OELV)	Workers Concentration C(Rp) as % of 400 mg/m <sup>3</sup> 8 hours - green cell <= OELV - red cell > OELV	Confidence range (LCL <-> UCL) of C(Rp) in mg/m <sup>3</sup> : - green cell UCL <= OELV, - yellow cell, brown characters LCL <= OELV <UCL, - red cell LCL >= OELV, - brown cell LCL<0.	UCL as % OELV (Red cell > OELV)
1	01-01-2021	worker1	124,000	480	480	480,00	12,0%	31%		
2	01-02-2021	worker1	63,000	480	480	480,00	6,0%	15,8%		
3	01-03-2021	worker1	274,000	480	480	480,00	27,0%	68,5%		
4	01-04-2021	worker2	44,000	480	480	480,00	4,0%	11%		
5	01-05-2021	worker2	8,000	480	480	480,00	0,0%	2%		
6	01-06-2021	worker2	23,000	480	480	480,00	2,0%	5,8%		
7	01-07-2021	worker3	239,000	480	480	480,00	23,0%	59,8%		
8	01-08-2021	worker3	94,000	480	480	480,00	9,0%	23,5%		
9	01-09-2021	worker3	114,000	480	480	480,00	11,0%	28,5%		
10	01-10-2021	worker4	45,000	480	480	480,00	4,0%	11,3%		
11	01-11-2021	worker4	53,000	480	480	480,00	5,0%	13,3%		
12	01-12-2021	worker4	47,000	480	480	480,00	4,0%	11,8%		
13	01-01-2022	worker5	43,000	480	480	480,00	4,0%	10,8%		
14	01-02-2022	worker5	32,000	480	480	480,00	3,0%	8%		
15	01-03-2022	worker5	97,000	480	480	480,00	9,0%	24,3%		
16	01-04-2022	worker6	73,000	480	480	480,00	7,0%	18,3%		
17	01-05-2022	worker6	49,000	480	480	480,00	4,0%	12,3%		
18	01-06-2022	worker6	48,000	480	480	480,00	4,0%	12%		


# Not part of this PBC but nice to know

- Testing compliance in different countries  $C_{95\%} > OELV$
- The influence of measurement uncertainty on  $C_{95\%}$



# Example: measurements of n-heptane

(AIHA 2015 4<sup>th</sup> edition)

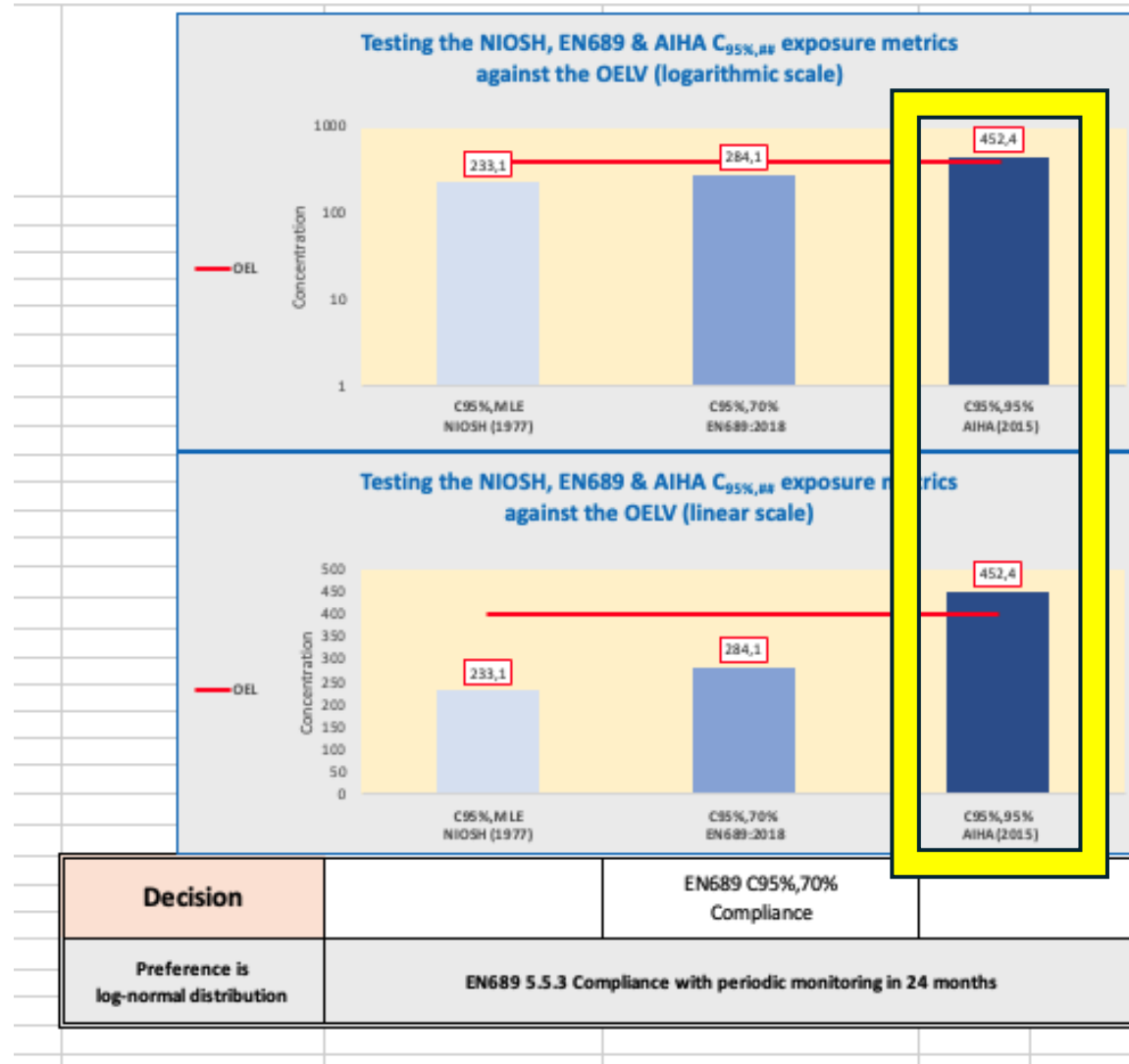
- 6 workers and 3 samples/worker
  - NL: OEL-TWA<sub>8h</sub>: 288 ppm (1200 mg/m<sup>3</sup>)=>1
  - **US: TLV-TWA: 400 ppm (1640 mg/m<sup>3</sup>) =>1** 
- Measurements based on HSE MDHS 72:
  - Methods for the determination of hazardous substances. Volatile organic compounds in air.
  - Coefficient of variation (CV<sub>t</sub>): **0.12**
- Relative expanded uncertainty = **2\*CV<sub>t</sub> = 24%**



Explanation	IH-Aligner			Version: 9.3.4-1	Person / Group / ID	C <sub>s</sub> OELV?	C <sub>s</sub> Extended Uncertainty <sub>s</sub> f(OELV)? - n=3: 10% OELV - n=4: 15% OELV - n=5: 20% OELV	C <sub>s</sub> Extended Uncertainty <sub>s</sub> OELV?	Result Preliminary test N=3-5
Sampled substance	Heptane (Paul Hewett) [AIHA-2015 4e edition] (TLV TWA US)			04-06-2024					
OELV	400,00	mg/m3							
Reference period OELV (Rp)	8 hours	480	minutes						
Daily Exposure duration SEG (If appropriate, change the default 480)	480			Personal Air Sampling method	sorbent tube, active with pump				
				Relative expanded Uncertainty (%) EN482 (2021) 6.1. g formula (4) & Annex B ISO-IEC Guide98-3 (2008)	24%				

	Date	Person / Group / ID	Measured concentration in mg/m3 (< sign before value in case of concentration below LoQ)	Total Sampling Duration (TSD) (minutes). Default 480	Worker's Exposure time t (minutes). Default 480	SEG Daily exposure duration or Workers Exposure time (t) (minutes)	Workers Concentration C(Rp) aligned to the OELV Reference period (Rp) (red cell > OELV)	Workers Concentration C(Rp) as % of 400 mg/m3 8 hours - green cell <= OELV - red cell > OELV	Confidence range (LCL <-> UCL) of C(Rp) in mg/m3: green cell UCL <= OELV, yellow cell, brown characters LCL <= OELV <UCL, red cell LCL >= OELV, brown cell LCL<0.	UCL as % OELV (Red cell > OELV)
1	01-01-2021	worker1	124,000	480	480	480,00	124,00	31%	[94,24 - 153,76]	38,4%
2	01-02-2021	worker1	63,000	480	480	480,00	63,00	15,8%	[47,88 - 78,12]	19,5%
3	01-03-2021	worker1	274,000	480	480	480,00	274,00	68,5%	[208,24 - 339,76]	84,9%
4	01-04-2021	worker2	44,000	480	480	480,00	44,00	11%	[33,44 - 54,56]	13,6%
5	01-05-2021	worker2	8,000	480	480	480,00	8,00	2%	[6,08 - 9,92]	2,5%
6	01-06-2021	worker2	23,000	480	480	480,00	23,00	5,8%	[17,48 - 28,52]	7,1%
7	01-07-2021	worker3	239,000	480	480	480,00	239,00	59,8%	[181,64 - 296,36]	74,1%
8	01-08-2021	worker3	94,000	480	480	480,00	94,00	23,5%	[71,44 - 116,56]	29,1%
9	01-09-2021	worker3	114,000	480	480	480,00	114,00	28,5%	[86,64 - 141,36]	35,3%
10	01-10-2021	worker4	45,000	480	480	480,00	45,00	11,3%	[34,2 - 55,8]	14%
11	01-11-2021	worker4	53,000	480	480	480,00	53,00	13,3%	[40,28 - 65,72]	16,4%
12	01-12-2021	worker4	47,000	480	480	480,00	47,00	11,8%	[35,72 - 58,28]	14,6%
13	01-01-2022	worker5	43,000	480	480	480,00	43,00	10,8%	[32,68 - 53,32]	13,3%
14	01-02-2022	worker5	32,000	480	480	480,00	32,00	8%	[24,32 - 39,68]	9,9%
15	01-03-2022	worker5	97,000	480	480	480,00	97,00	24,3%	[73,72 - 120,28]	30,1%
16	01-04-2022	worker6	73,000	480	480	480,00	73,00	18,3%	[55,48 - 90,52]	22,6%
17	01-05-2022	worker6	49,000	480	480	480,00	49,00	12,3%	[37,24 - 60,76]	15,2%
18	01-06-2022	worker6	48,000	480	480	480,00	48,00	12%	[36,48 - 59,52]	14,9%


# TLV-TWA = 400 ppm | Compliance?



AIHA 2015  
 $C_{95\%, 95\%} > 400 \text{ ppm}$   
**Clearly unacceptable exposure profile**

# Example: measurements of n-heptane

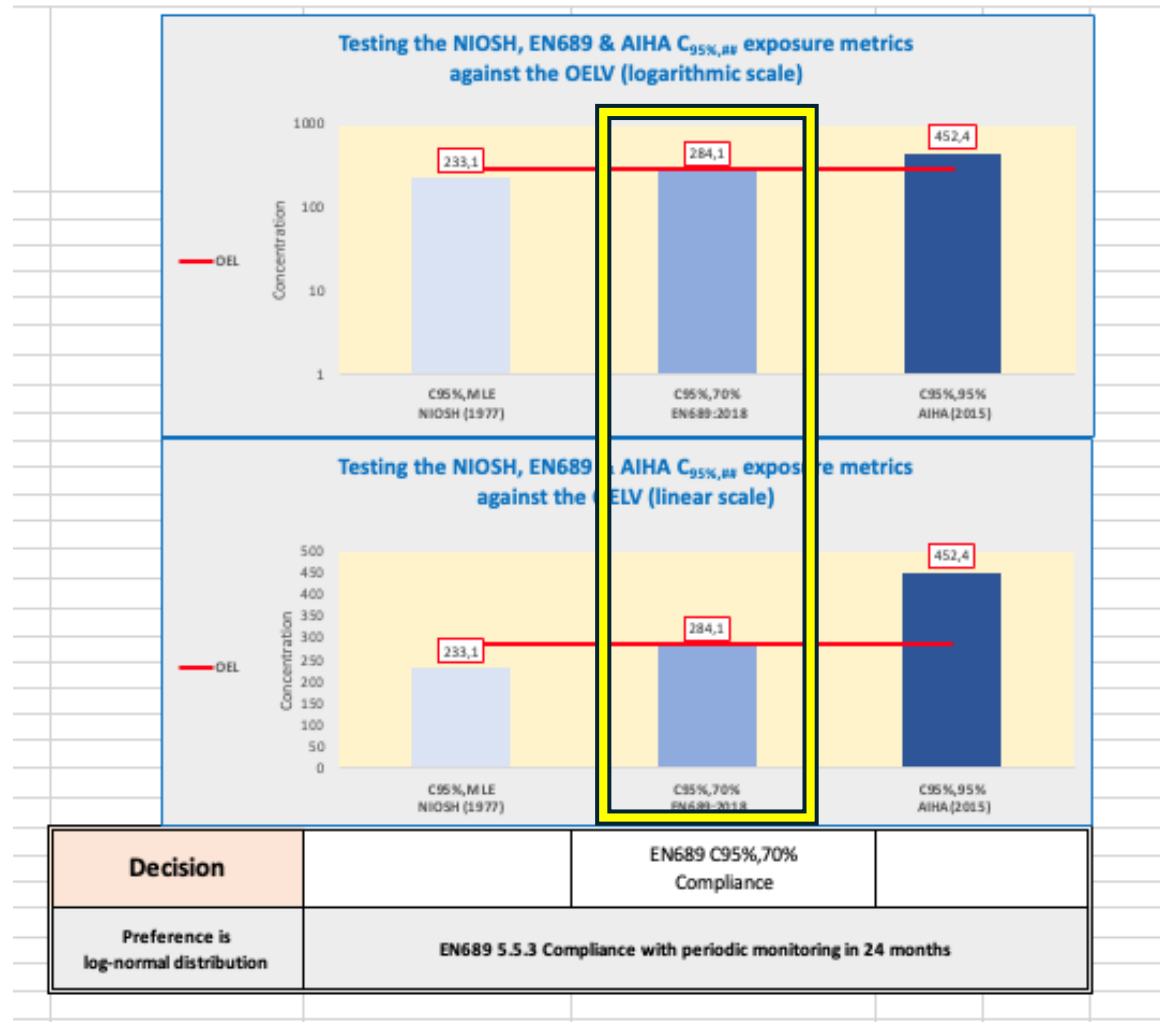
EN 689 2018:A 2019

- 6 workers and 3 samples/worker
  - **NL: OEL-TWA<sub>8h</sub>: 288 ppm (1200 mg/m<sup>3</sup>)=>1** 
  - US: TLV-TWA: 400 ppm (1640 mg/m<sup>3</sup>) =>1
- Measurements based on HSE MDHS 72:
  - Methods for the determination of hazardous substances. Volatile organic compounds in air.
  - Coefficient of variation (CV<sub>t</sub>): **0.12**
- Relative expanded uncertainty = **2\*CV<sub>t</sub> = 24%**

Explanation	IH-Aligner			Version: 9.3.4-I	Person / Group / ID	C <sub>s</sub> OELV?	C <sub>s</sub> +Extended Uncertainty <sub>s</sub> f(OELV)? - n<=3: 10% OELV - n=4: 15% OELV - n=5: 20% OELV	C <sub>s</sub> +Extended Uncertainty <sub>s</sub> OELV?	Result Preliminary test N=3-5
Sampled substance	Heptane (Paul Hewett) [AIHA-2015 4e edition] (TLV TWA US)			04-06-2024					
OELV	288,00	mg/m <sup>3</sup>							
Reference period OELV (Rp)	8 hours	480	minutes						
Daily Exposure duration SEG (if appropriate, change the default 480)	480				Personal Air Sampling method	sorbent tube, active with pump			
					Relative expanded Uncertainty (%) EN482 (2021) 6.1. g formula (4) & Annex B ISO-IEC Guide98-3 (2008)	24%			

	Date	Person / Group / ID	Measured concentration in mg/m <sup>3</sup> (< sign before value in case of concentration below LoQ)	Total Sampling Duration (TSD) (minutes). Default 480	Worker's Exposure time t (minutes). Default 480	SEG Daily exposure duration or Workers Exposure time (t) (minutes)	Workers Concentration C(Rp) aligned to the OELV Reference period (Rp) (red cell > OELV)	Workers Concentration C(Rp) as % of mg/m <sup>3</sup> 8 hours green cell <= OELV red cell > OELV	Confidence range (LCL <-> UCL) of C(Rp) in mg/m <sup>3</sup> : - green cell UCL <= OELV, - yellow cell, brown characters LCL <= OELV <UCL, - red cell LCL >= OELV, - brown cell LCL<0.	UCL as % OELV (Red cell > OELV)
1	01-01-2021	worker1	124,000	480	480	480,00	124,00	43,1%	[94,24 - 153,76]	53,4%
2	01-02-2021	worker1	63,000	480	480	480,00	63,00	21,9%	[47,88 - 78,12]	27,1%
3	01-03-2021	worker1	274,000	480	480	480,00	274,00	95,1%	[208,24 - 339,76]	118%
4	01-04-2021	worker2	44,000	480	480	480,00	44,00	15,3%	[33,44 - 54,56]	18,9%
5	01-05-2021	worker2	8,000	480	480	480,00	8,00	2,8%	[6,08 - 9,92]	3,4%
6	01-06-2021	worker2	23,000	480	480	480,00	23,00	8%	[17,48 - 28,52]	9,9%
7	01-07-2021	worker3	239,000	480	480	480,00	239,00	83%	[181,64 - 296,36]	102,9%
8	01-08-2021	worker3	94,000	480	480	480,00	94,00	32,6%	[71,44 - 116,56]	40,5%
9	01-09-2021	worker3	114,000	480	480	480,00	114,00	39,6%	[86,64 - 141,36]	49,1%
10	01-10-2021	worker4	45,000	480	480	480,00	45,00	15,6%	[34,2 - 55,8]	19,4%
11	01-11-2021	worker4	53,000	480	480	480,00	53,00	18,4%	[40,28 - 65,72]	22,8%
12	01-12-2021	worker4	47,000	480	480	480,00	47,00	16,3%	[35,72 - 58,28]	20,2%
13	01-01-2022	worker5	43,000	480	480	480,00	43,00	14,9%	[32,68 - 53,32]	18,5%
14	01-02-2022	worker5	32,000	480	480	480,00	32,00	11,1%	[24,32 - 39,68]	13,8%
15	01-03-2022	worker5	97,000	480	480	480,00	97,00	33,7%	[73,72 - 120,28]	41,8%
16	01-04-2022	worker6	73,000	480	480	480,00	73,00	25,3%	[55,48 - 90,52]	31,4%
17	01-05-2022	worker6	49,000	480	480	480,00	49,00	17%	[37,24 - 60,76]	21,1%
18	01-06-2022	worker6	48,000	480	480	480,00	48,00			

# NL\_OELV-TWA = 288 ppm | Compliance?





Explanation	IH-Aligner			Version: 9.3.4-I	Person / Group / ID	C <sub>s</sub> OELV?	C <sub>s</sub> +Extended Uncertainty <sub>s</sub> f(OELV)? - n<=3: 10% OELV - n=4: 15% OELV - n=5: 20% OELV	C <sub>s</sub> +Extended Uncertainty <sub>s</sub> OELV?	Result Preliminary test N=3-5
Sampled substance	Heptane (Paul Hewett) [AIHA-2015 4e edition] (TLV TWA US)			04-06-2024					
OELV	288,00	mg/m3							
Reference period OELV (Rp)	8 hours	480 minutes							
Daily Exposure duration SEG (if appropriate, change the default 480)	480			Personal Air Sampling method	sorbent tube, active with pump				
				Relative expanded Uncertainty (%) EN482 (2021) 6.1. g formula (4) & Annex B ISO-IEC Guide98-3 (2008)	24%				

	Date	Person / Group / ID	Measured concentration in mg/m3 (< sign before value in case of concentration below LoQ)	Total Sampling Duration (TSD) (minutes). Default 480	Worker's Exposure time t (minutes). Default 480	SEG Daily exposure duration or Workers Exposure time (t) (minutes)	Workers Concentration C(Rp) aligned to the OELV Reference period (Rp) (red cell > OELV)	Workers Concentration C(Rp) as % of 288 mg/m3 8 hours - green cell <= OELV - red cell > OELV	Confidence range (LCL <-> UCL) of C(Rp) in mg/m3: - green cell UCL <= OELV, - yellow cell, brown characters LCL <= OELV <UCL, - red cell LCL >= OELV, - brown cell LCL<0.	UCL as % OELV (Red cell > OELV)
1	01-01-2021	worker1	124,000	480	480	480,00	124,00	43,1%	[94,24 - 153,76]	53,4%
2	01-02-2021	worker1	63,000	480	480	480,00	63,00	21,9%	[43,88 - 78,12]	27,8%
3	01-03-2021	worker1	274,000	480	480	480,00	274,00	95,1%		
4	01-04-2021	worker2	44,000	480	480	480,00	44,00	15,3%		
5	01-05-2021	worker2	8,000	480	480	480,00	8,00	2,8%		
6	01-06-2021	worker2	23,000	480	480	480,00	23,00	8%		
7	01-07-2021	worker3	239,000	480	480	480,00	239,00	83%		
8	01-08-2021	worker3	94,000	480	480	480,00	94,00	32,6%	[71,44 - 116,56]	40,3%
9	01-09-2021	worker3	114,000	480	480	480,00	114,00	39,6%	[86,64 - 141,36]	49,1%
10	01-10-2021	worker4	45,000	480	480	480,00	45,00	15,6%	[34,2 - 55,8]	19,4%
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13	01-01-2022	worker5	43,000	480	480	480,00	43,00	14,9%	[32,68 - 53,32]	18,5%
14	01-02-2022	worker5	32,000	480	480	480,00	32,00	11,1%	[24,32 - 39,68]	13,8%
15	01-03-2022	worker5	97,000	480	480	480,00	97,00	33,7%	[73,72 - 120,28]	41,8%
16	01-04-2022	worker6	73,000	480	480	480,00	73,00	25,3%	[55,48 - 90,52]	31,4%
17	01-05-2022	worker6	49,000	480	480	480,00	49,00	17%	[37,24 - 60,76]	21,1%
18	01-06-2022	worker6	48,000	480	480	480,00	48,00	16,7%	[36,48 - 59,52]	20,7%

**Exceedance of OELV is possible!**

# BWStat v 3.1.0

Substance name

Heptane

Measurement unit

Backgrounds, details and consequences next Thursday in Theo's presentation; session 11B Room 1872 (Exposure assessment).

Monte Carlo trials:  $1e+05$

UTL<sub>u</sub> : 285

cv<sub>u</sub> : 0.0412

coverage interval : [ 262 , 308 ]

exposure index : [ 0.91 , 1.1 ]

Non-compliance?

GMI (data) : 00.507

GSD (data): 2.273

Ucrit = UT: 1.886

UR (data) : 1.903

**With measurement uncertainty (by Monte Carlo)**

Monte Carlo trials:  $1e+05$

UTL<sub>u</sub> : 285

cv<sub>u</sub> : 0.0412

coverage interval : [ 262 , 308 ]

exposure index : [ 0.91 , 1.1 ]



# The rehab of measurement uncertainty in exposure assessment

Robert Emonds, Theo Scheffers, Peter van Balen

13-06-2024 session-D 11B IOHA Dublin Room 1872

