

# Improvement of work practices for safe use of formaldehyde in a university-based anatomy teaching and research facility

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# Health hazards of formaldehyde

- Short-term exposure: Sensory irritation of eyes and mucous membranes of upper airways (~5 % of the population has a hypersensitive response)
- Long-term exposure: sufficient evidence for nasopharyngeal cancer, limited evidence for cancer of the nasal cavity and paranasal sinuses.  
IARC: *“The Working Group was not in full agreement on the evaluation of formaldehyde causing leukemia”*



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# Biomarkers for genotoxic damage

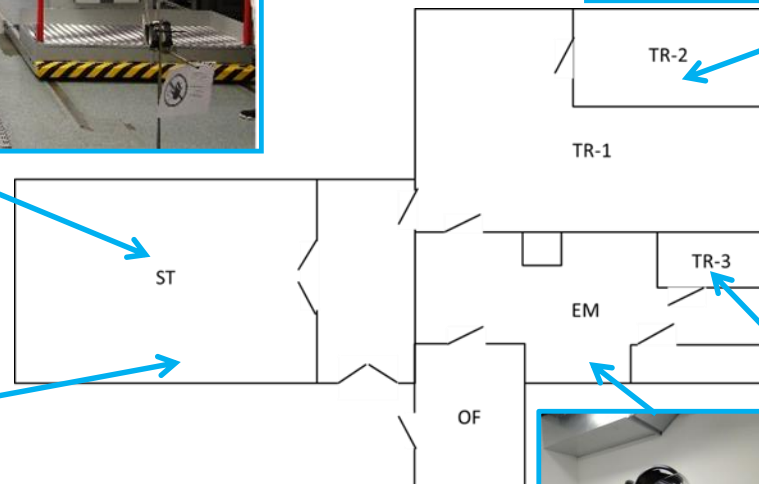
- Netherlands: OEL for 8-h is **150  $\mu\text{g}/\text{m}^3$**  and for 15-min is **500  $\mu\text{g}/\text{m}^3$**
- Portugal: Increased **frequency of chromosomal aberrations and comets** in anatomy pathology workers exposed to (mean  $\pm$  sd): **475  $\pm$  38  $\mu\text{g}/\text{m}^3$**   
Costa et al. *Mutagenesis* 2015, 30, 463–473
- Slovenia: OR of 1.7 (CI 1.1-2.7) for increased **frequency of chromosomal aberrations** associated with exposure of workers in a pathology anatomy laboratory to **320 (range: 140-660)  $\mu\text{g}/\text{m}^3$**   
Musak et al. *Scand J Work Environ Health* 2013;39(6):618-630
- Italy: Increased **frequency of leucocyte malondialdehyde-deoxyguanosine M[1]-dG adducts** in pathologists exposure to formaldehyde > **66  $\mu\text{g}/\text{m}^3$**   
Bono et al. *Chem. Res. Toxicol.* 2010, 23, 1342–1348

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# Aims

- Raise awareness regarding hazard classification of formaldehyde
- Evaluate current exposure according to occupational exposure limits in the Netherlands: 150  $\mu\text{g}/\text{m}^3$  for 8-h and 500  $\mu\text{g}/\text{m}^3$  for 15-min
- Implement improved work practices: technical infrastructure and work practices

# Gross anatomy facility



# Technical information

Room	Size (m <sup>2</sup> )	Function	Facilities	Air exchange rate (h <sup>-1</sup> )		Air Exchange/table (h <sup>-1</sup> )	
				Design	Effective <sup>a</sup>	Design	Effective <sup>a</sup>
Storage	164	Storage of cadavers and specimens	Storage of human remains in 75 tanks with lifting equipment and 37% FA stock	6.1	6.3	- <sup>c</sup>	- <sup>c</sup>
Embalming	89	Tap water flushing	Work bench with water taps	8.8	9.0	- <sup>c</sup>	-
TR-1	199	Instruction	16 dissection tables	15.3	14.2	0.96	0.89
TR-2	64	Instruction	6 dissection tables	31.3	23.7	5.2	4.0
TR-3	17	Research projects	2 dissection tables	19.5	4.6 <sup>b</sup>	9.8	2.3 <sup>b</sup>

<sup>a</sup> Measurement using CO<sub>2</sub> as a tracer (measurements performed in March 2012); <sup>b</sup> Technical malfunction (returned to 11.4 per hour after repair, leading to a capacity per table of 5.7 per hour); <sup>c</sup> - not measured. **Radboudumc**

# Use of formalin in anatomy department

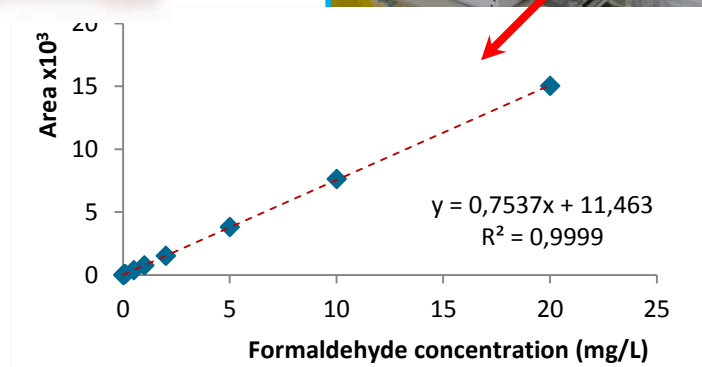
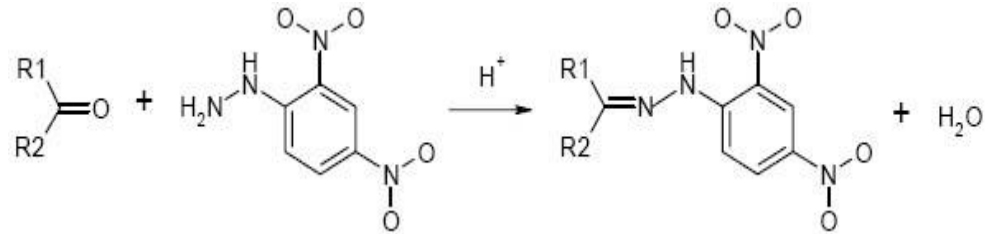
OSHA 1007 en NIOSH 2016

Silicagel impregnated with 2,4-dinitrophenylhydrazine (2,4-DNPH)

HPLC-UV (360 nm)

Agilent Eclipse XDB-C18, 150 x 4,6 mm, 5 µm i.d.

BCR reference material: 4.96 +/- 0.06 µg/filter





# Use of formalin in anatomy department

Occupational exposure limit (OEL) time-weighted average for 8-h of  $0.15 \text{ mg/m}^3$

Workplace	Duration	N	Not compliant	Geometric mean ( $\text{mg/m}^3$ )	% of OEL
Training rooms	2 h	5	2	0.11	73
Storage	8 h	1	1	0.16	107
Embalming	6 h	1	1	1.12	747
<b>All observations</b>	<b>2-8 h</b>	<b>7</b>	<b>4</b>	<b>0.17</b>	<b>115</b>



*Preparation (2007)*



# Use of formalin in anatomy department

Occupational exposure limit (OEL): time-weighted average for 15-min of 0.50 mg/m<sup>3</sup>

Workplace	Duration	N	Not compliant	Geometric mean (mg/m <sup>3</sup> )	% of OEL
Training rooms	15 min	3	0	0.22	44
Storage	15 min	2	2	0.80	160
Embalming	15 min	2	1	0.39	78
<b>All observations</b>	<b>15 min</b>	<b>7</b>	<b>3</b>	<b>0.37</b>	<b>74</b>



*Storage (2007)*

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# Occupational hygiene strategy

- **Eliminate**/substitute
- Technical solutions to **segregate**
- **Organize** the work
- Adapt the person to the work by **protection**



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# 1. Eliminate/substitute

Is it possible to eliminate the source or find a substitute?

- Can formalin be eliminated/substituted? Perhaps

For *some* applications such as displays of preparations in museums/expositions

Plastination technique developed by *dr. Gunther von Hagens* at the University of Heidelberg's Institute of Anatomy in 1977

## Limitations:

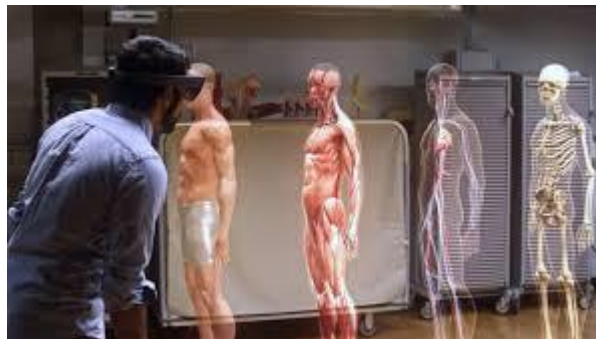
- You still need formalin in the first step of the process
- You need acetone and acrylate monomers to produce the plastic



# 1. Eliminate/substitute

Is it possible to eliminate the source or find a substitute?

- Augmented reality
- Virtual reality





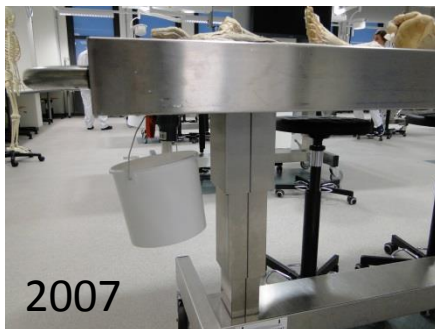
## 2. Segregate

Is it possible to segregate the worker from the source?

Also looks nice, does it work? ... and does this work?

### Storage

Prevent  
evaporation  
from spills  
in storage



## 2. Segregate

Is it possible to segregate the worker from the source?

### Preparation

Use of local exhaust ventilation (LEV) when flushing body parts with water to reduce formaldehyde emissions during anatomy lessons



It looks nice ... but does it also work nicely?



## 2. Segregate

Is it possible to segregate the worker from the source?

Down-flow room ventilation  
at the location where large  
body parts are mechanically  
lifted from the storage tanks



This looks sophisticated but ... does it work?





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# 3. Organize

Is it possible to organize the tasks in a better way?

The workers themselves proposed to organize workflow in the storage differently:

- Old practice  
Collect anatomy preparations for required anatomy lesson/course from different tanks
- New practice  
All anatomy preparations needed for one anatomy lesson/course will be combined in a single tank. The number of tasks is reduced and thus exposure



# 4. Protection

Is it possible to protect the worker better?

APF = assigned protection factor

Poor fit (APF=10)

Not protective: (APF=1)

Air stream helm with dedicated formaldehyde filter protection of eyes and airways (APF=25)

Full face respirator with double filters for low breathing resistance protection of eyes and airways (APF=50)



# Changes in work practices

Category	No.	Description	Old Work Practice	New Work Practice	Location/Room
Technical	T-1	Leak prevention	For of	co ge	Storage
	T-2	Elimination of disposable absorbent sheets	Spe di	El she	Teaching
	T-3	Introduction of local exhaust ventilation (LEV)	wh with		Embalming
	T-4	Improvement of down flow ventilation (DFV)	Do spe	In re ne	Storage
Organisation	O-1	Optimizing storage system <sup>a</sup>	Specimens storage methods did not match with teaching programme	Reduce number of tanks to be opened to retrieve the required specimens.	Storage
	O-2	Tap water flushes and reduction of exposure time	Overnight flushing of specimens by tap water	Extension of the flush time and reduction of the time that specimens are put on display.	Embalming

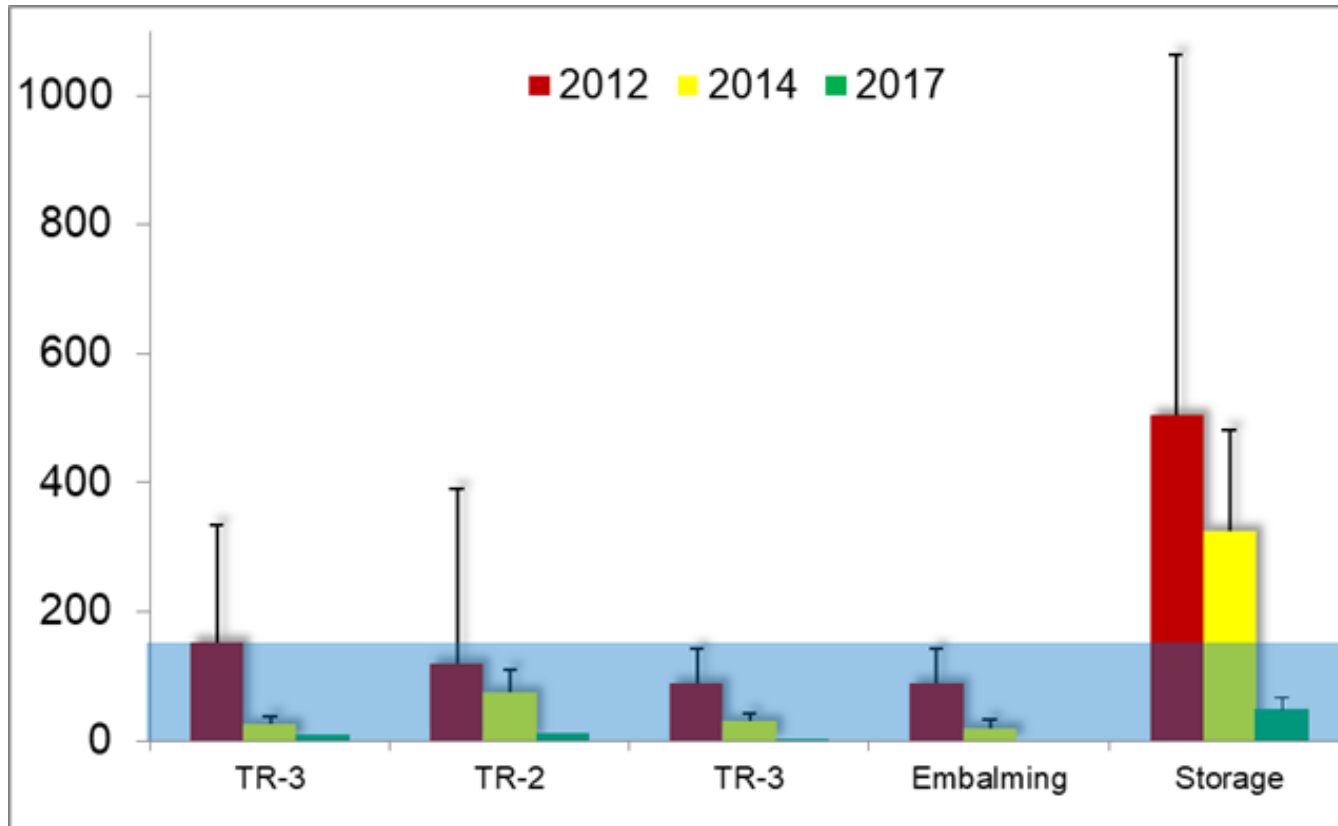
<sup>a</sup> Introduction of this new practice is still on-going. Currently this provision is in place for a few courses.

# Changes at fixed locations (8-h samples)

Room	2012			2014			2017		
	<i>n</i>	GM	Range	<i>n</i>	GM	Range	<i>n</i>	GM	Range
TR-1	10	80.4	49–618.3	4	21.2	7.7–38.6	1	9.0 <sup>c</sup>	– <sup>c</sup>
TR-2	6	10.9	2.2–672.2 <sup>a</sup>	4	69.8	50.3–124.6	1	13.0 <sup>c</sup>	– <sup>c</sup>
TR-3	-	-	-	4	16.2	10.1–40.0	1	1.6 <sup>c</sup>	– <sup>c</sup>
Embalming	10	74.7	37.3–169.9	4	27.4	16.7–41.7	0	– <sup>c</sup>	– <sup>c</sup>
Storage	10	290.9	89.7–1506.2	4	301.7	206.5–554.0	2	62.5, 34.9 <sup>b,c</sup>	– <sup>c</sup>

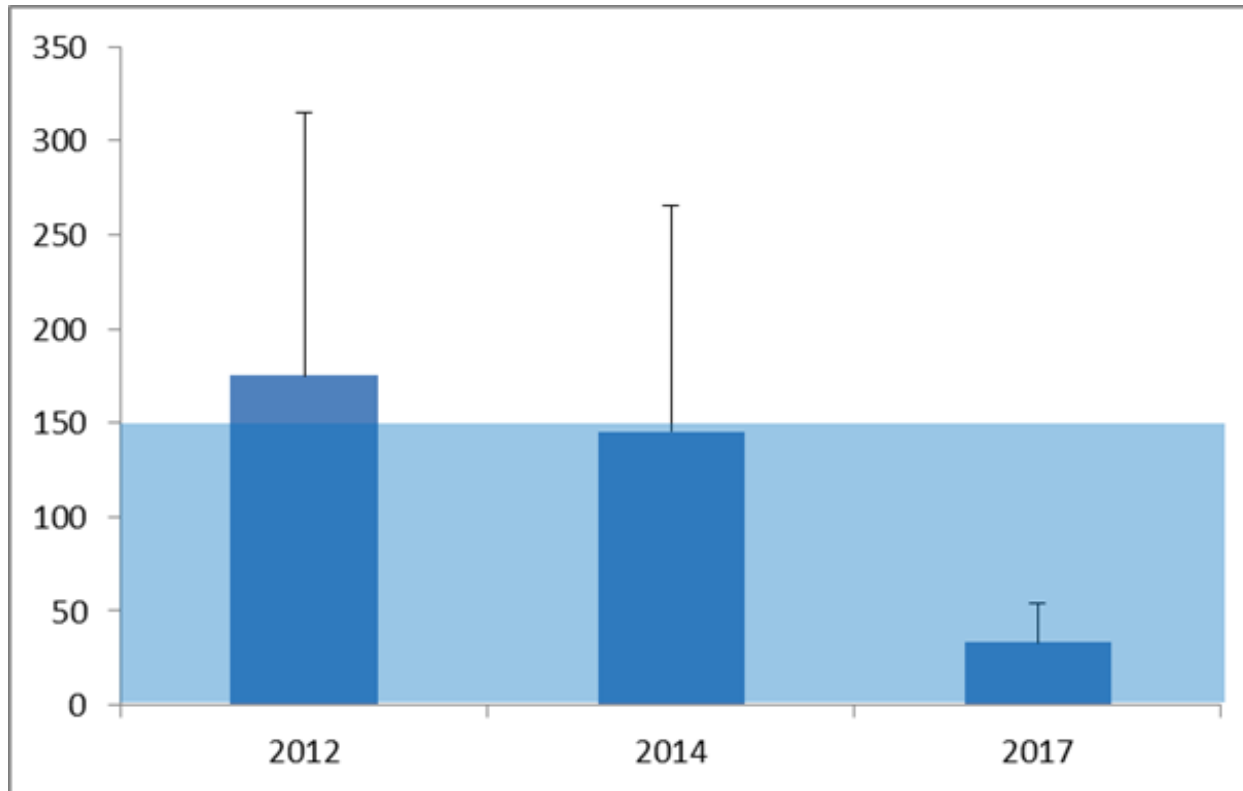
<sup>a</sup> At exhaust; <sup>b</sup> Two single measurements: one near field and one far field measurement, respectively; <sup>c</sup> not calculated.

# 8-h measurements at fixed locations



**Figure 8.** Mean  $\pm$  sd FA concentrations ( $\mu\text{g}/\text{m}^3$ ) at fixed locations in rooms of the anatomy facility. The shaded area indicates the 8-h TWA OEL of  $150 \mu\text{g}/\text{m}^3$  for FA in The Netherlands.

## Breathing zone 8-h TWA workers and students



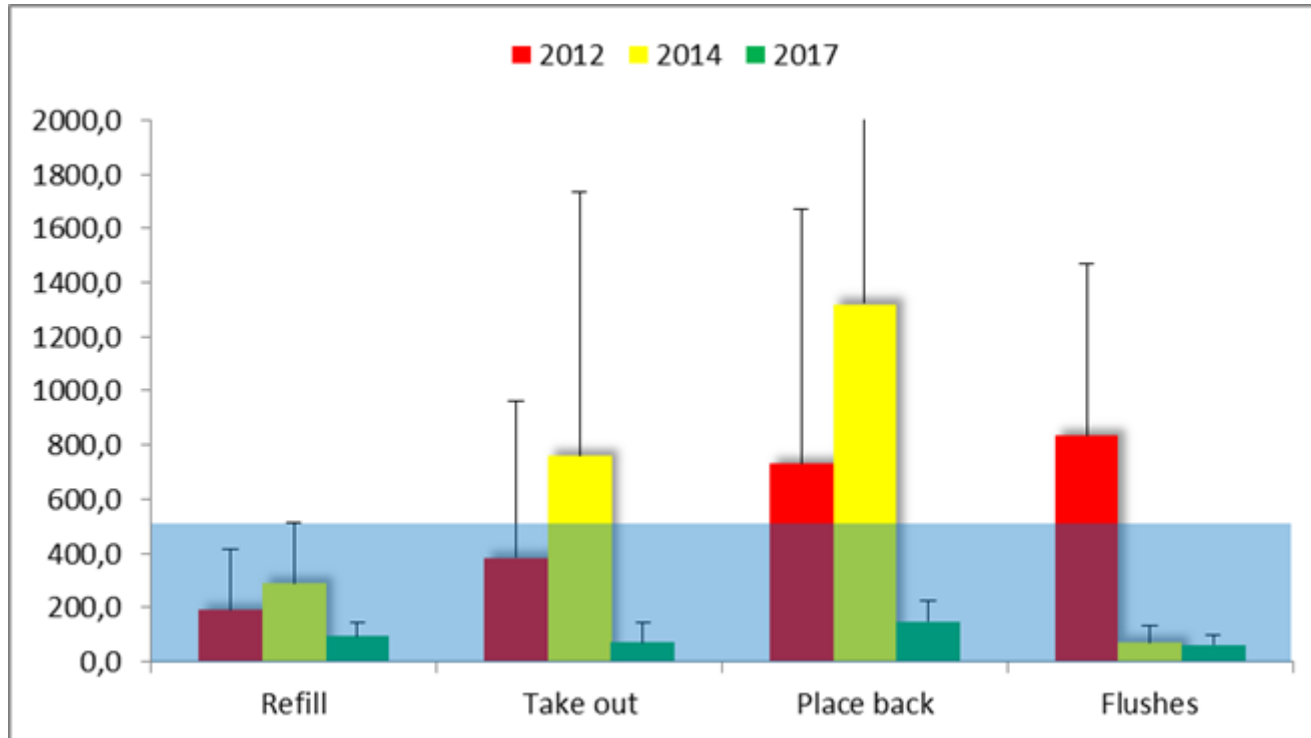
**Figure 9.** Mean  $\pm$  sd FA concentrations ( $\mu\text{g}/\text{m}^3$ ) in the breathing zone of workers and students during a full shift. The shaded area indicates the 8-h TWA OEL of  $150 \mu\text{g}/\text{m}^3$  for FA in The Netherlands.

# Breathing zone concentrations (8-h)

Year	Group	<i>n</i>	GM	P <sub>95</sub>	Range	Non-Compliance (%)
2012	Workers	21	123.0	407.9	17.2–519.7	42.8
	Students	5	174.7	930.0	117.0–1120	60.0
	<b>Total</b>	<b>26</b>	<b>131.6</b>	<b>491.7</b>	<b>17.2–1120</b>	<b>46.2</b>
2014	Workers	8	121.3	252.8	55.6–287.3	37.5
	Students	5	102.8	405.6	49.6–468.9	40.0
	<b>Total</b>	<b>13</b>	<b>113.6</b>	<b>359.9</b>	<b>49.6–468.9</b>	<b>38.5</b>
2017	Workers	6	26.5	61.9	10.6–71.8	0
	Students	7	30.9	68.0	19.6–80.1	0
	<b>Total</b>	<b>13</b>	<b>28.8</b>	<b>75.1</b>	<b>10.6–80.1</b>	<b>0</b>



# Task-based measurements breathing zone



**Figure 10.** Mean  $\pm$  sd FA concentrations ( $\mu\text{g}/\text{m}^3$ ) in the breathing zone during specific tasks. The shaded area indicates the 15-min TWA OEL of  $500 \mu\text{g}/\text{m}^3$  for FA in the Netherlands

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# Discussion

- Peak exposures are difficult to assess due to lack of reliable direct reading instruments (cross-reactivity with alcohols)
- Skin exposure should be included in an overall exposure assessment because of the sensitizing properties of formaldehyde
- Formalin is buffered with methanol as stabilizer (degradation product) and has reproductive toxic properties that should be addressed in future occupational hygiene measurements

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# Conclusion

- The occupational hygiene strategy offers a useful framework to explore improved work practices
- Most interventions are insufficiently evidence-based and need verification in occupational hygiene studies
- Worker's and employer's participation contributes to improvements to be sustainable.



Scheepers et al. (2018) Changes in Work Practices for Safe Use of Formaldehyde in a University-Based Anatomy Teaching and Research Facility. Int. J. Environ. Res. Public Health 2018, 15(9), 2049; <https://doi.org/10.3390/ijerph15092049>

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# Acknowledgements

## Staff and students of the Department of Anatomy

- Vera Gelsing
- Albert van Linge

## Technical staff

- Ronald Jansen

## Occupational and Environmental Service

- Cora Klaver

## Lab Technicians

- Rob Anzion
- Gwendolyn Beckmann
- Maurice van Dael

## BSc, MSc and PhD Students

- Martien Graumans
- Maarten Melissen
- Nicole Pinckaers
- Luuk van Wel
- Laurie de Werdt



Members of an emergency response team 'fit-for-the-job'  
Chemical company in the Netherlands in the 1930's (courtesy DSM)