1st International Seminar on Environmental Odour Management 2014

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Considerations on Sampling and Measurement of Odours (VDI 3880 & VDI 3885/1) and enoses

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(Chair from 1998 to 2011)
Chair, DWA Committee "Emissions of waste water facilities"

Deutschland Land der Ideen
Ausgewählter Ort 2011
und Bundessieger „Gesellschaft"

VDI 3880 "Olfactometry – Static sampling"

VDI 3880 “Olfactometry – Static sampling”

General Requirements on Sampling

- Working conditions
- Sampling equipment
- Sampling bag
- Performance of sampling for delayed olfactometry
- Predilution
- Sampling duration: 30 minutes
- Number of samples: min. 3 samples/source and operation condition
- Samples Storage: < 6h, or stability has to be proven: 6 measurements (3 immediately after sampling, 3 after desired storage time, difference of more than a factor of 1.5 is not acceptable)
- Sample transport

VDI 3880 "Olfactometry – Static sampling"

- Performance of sampling in relation of source types
  - Demarcation of active and passive sources
  - Active sources ("diffuse sources" in EN 13725)
  - Passive sources ("aerated diffuse sources" in EN 13725)
- Quality assurance

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source types according to VDI 3880

air volume flow

measurable
5.2 Active sources

>30 m/h

5.2.1 Active point sources
EN: Point Source

5.2.2 Active area sources
EN: Aerated diffuse sources

not measurable
5.3 Passive sources

< 30 m/h

EN: Fugitive Sources

5.3.2 Passive area sources
EN: Diffuse Sources

5.3.3 Volume sources

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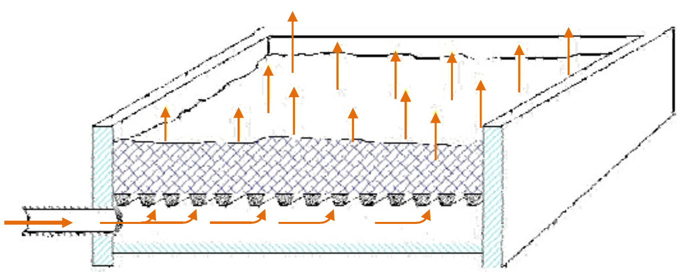
types of sources

active point source:
e.g. stack

passive area source: e.g. landfill, wwtp, composting

active area source:
e.g. biofilter



volume source: e.g. building

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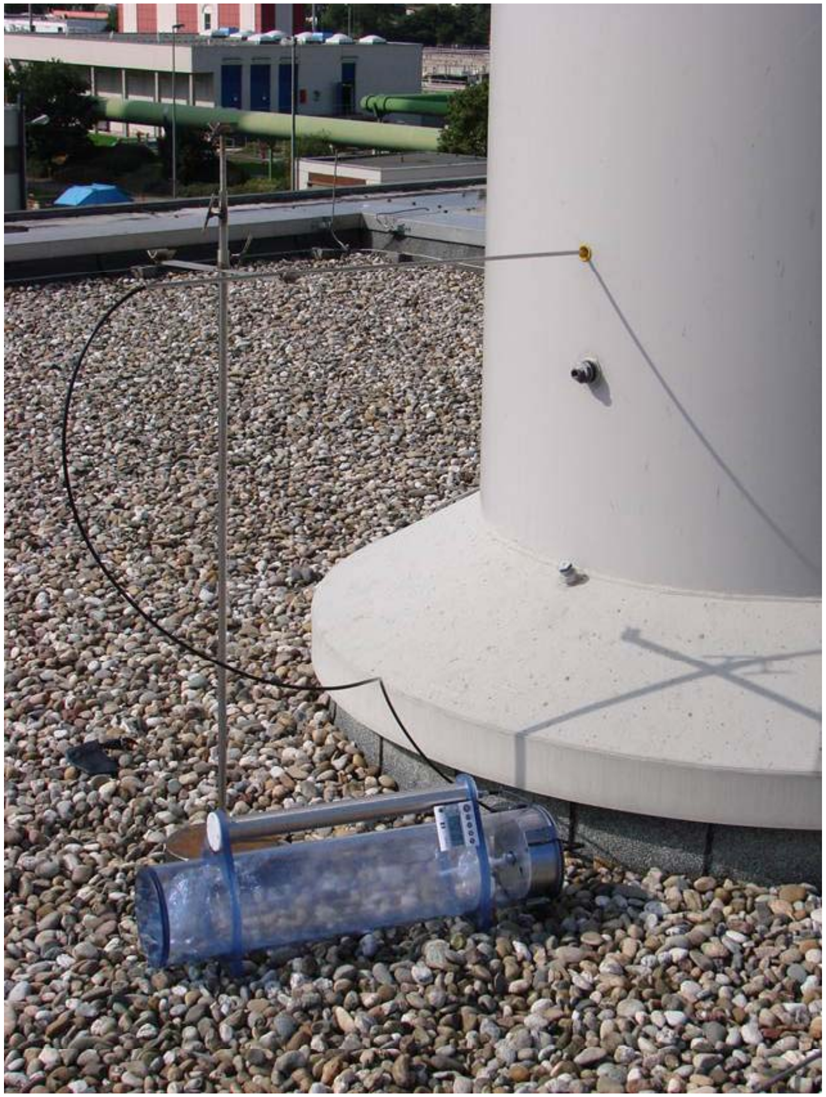
active point: stack



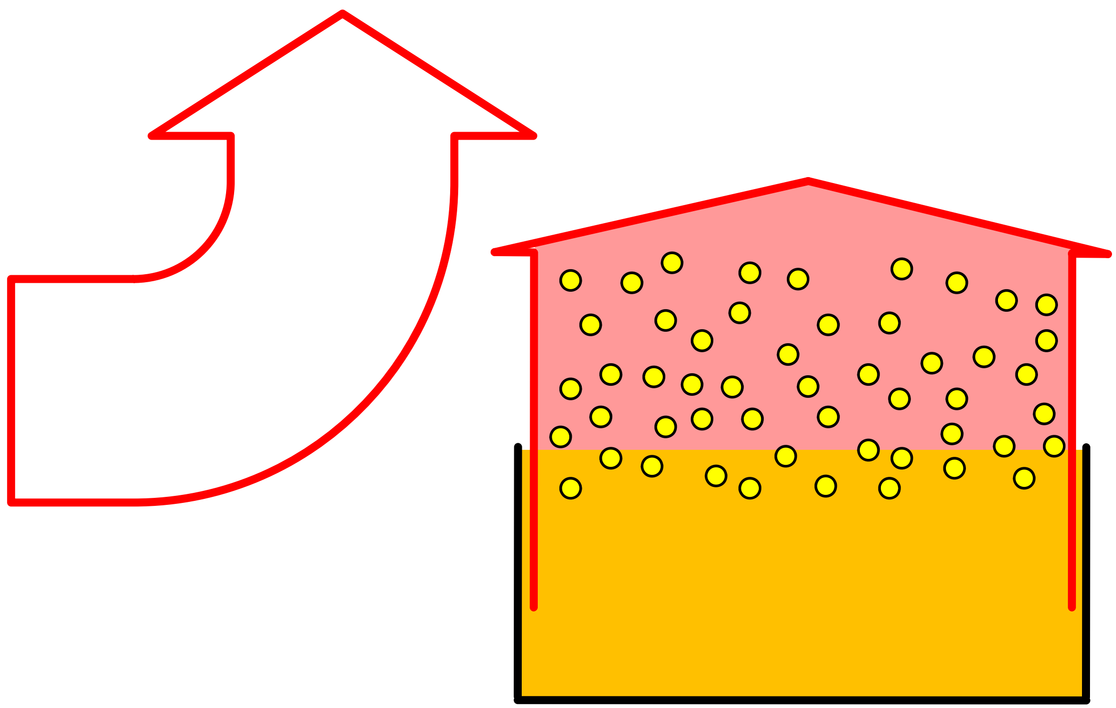
active point: stack

Table 4. Minimum number of measurement points in the respective measurement cross section for studying gaseous emissions, evenly distributed on measurement axes

Area of the measuremen cross section A/m^2	**Number of measurement points** (round cross section) n_r	**Number of measurement points** (rectangular cross section) n_e
< 0.20	1	1
0.21 to 1.00	4	4
1.01 to 2.00	8	9
> 2.00	12	12

source: DIN 4200 (Dec. 2000)

Scheme of an active area source
Hood or total cover to be used



active area: hood or complete cover?

- the advantage of a **complete cover** is that the entire waste gas stream is emitted via one defined orifice and the determination of the total source strength is possible by measuring here, taking only three samples. The total odour flow rate can thus be reliably determined.

active area sources, e.g. biofilter: complete cover

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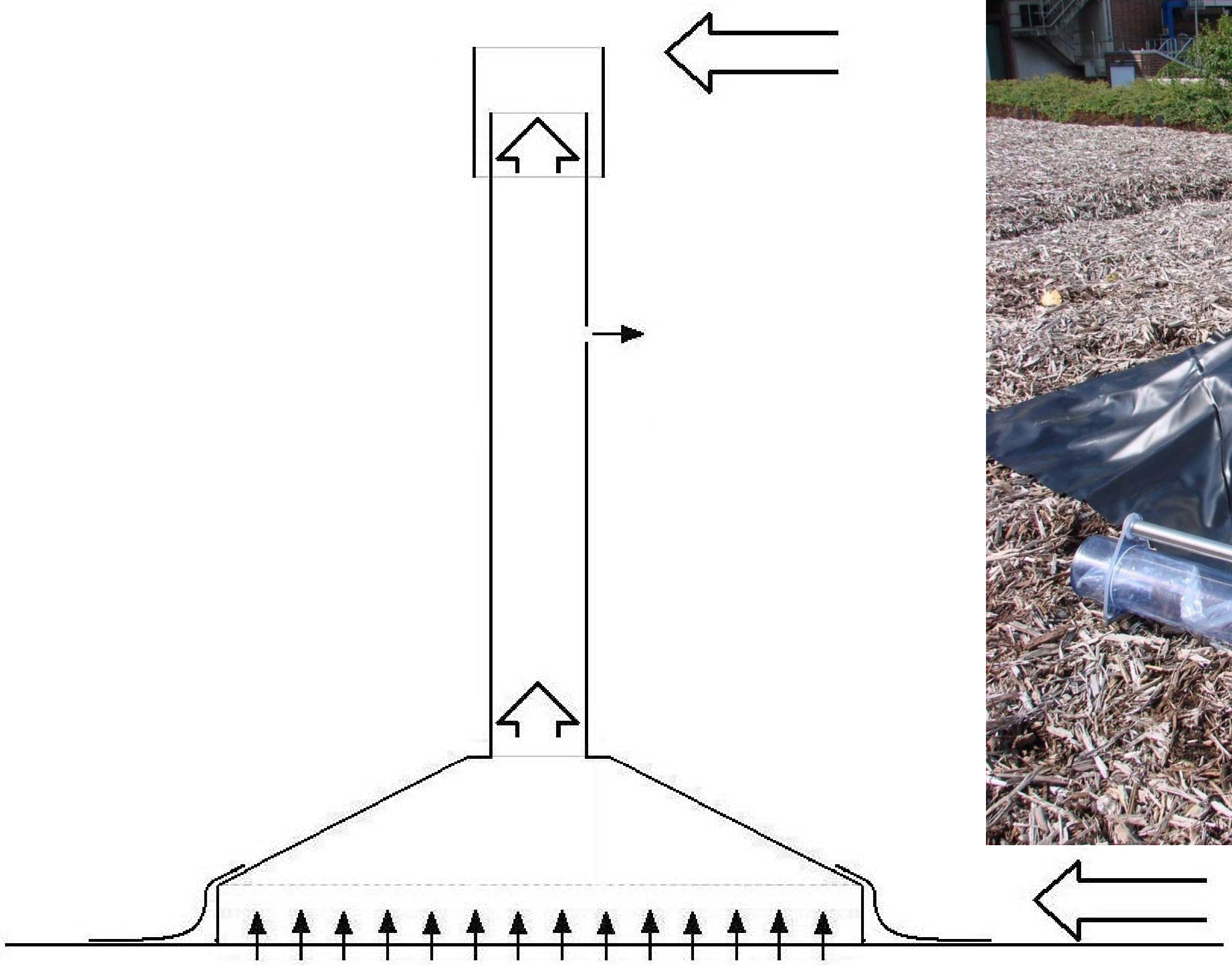
active area: hood or complete cover?

- the advantage of a **complete cover** is that the entire waste gas stream is emit-ted via one defined orifice and the determination of the total source strength is possible by measuring here, taking only three samples. The total odour flow rate can thus be reliably determined.
- usage of the **hood method** is beneficial if, in addition to the overall odour flow rate, a meaningful statement is required on the condition of the source (e.g. biofilter function) and its optimization. Only with point sampling inhomogeneous areas (flow velocity, odour concentration) can be detected, delivering a better picture of the state of individual part areas and regions of, e.g., a biofilter.
- the decision depends on technical possiubility and question to be answered!

active area sources, e.g. biofilter: hood



active area sources, e.g. biofilter: hood

- how many points have to be sampled?
  - *Rectangular sources are subdivided into a grid of part areas that are as square as possible.*
  - *In the case of ground areas up to 100 m², part areas are to be created of at least approximately 10 m² each. At least four part areas are to be formed on ground areas < 40 m².*
  - *In the case of ground areas upwards of 100 m² to 2 000 m², at least one further part area is to be additionally created per roughly 100 m².*
  - *For ground areas > 2 000 m², 30 part areas are usually sufficient.«*

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passive sources: how to sample - no airflow present?

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passive sources: how to sample - no airflow present?

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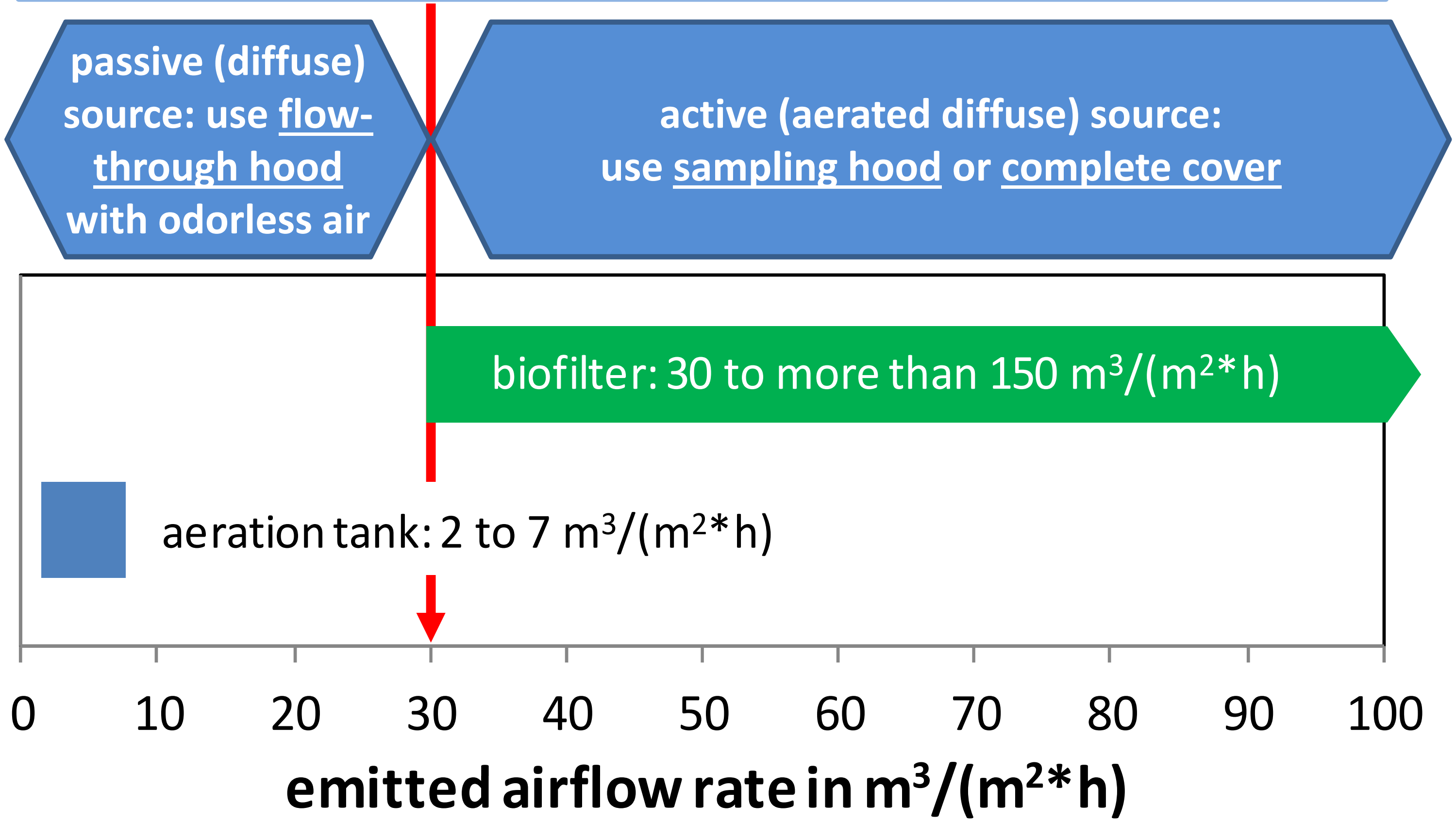
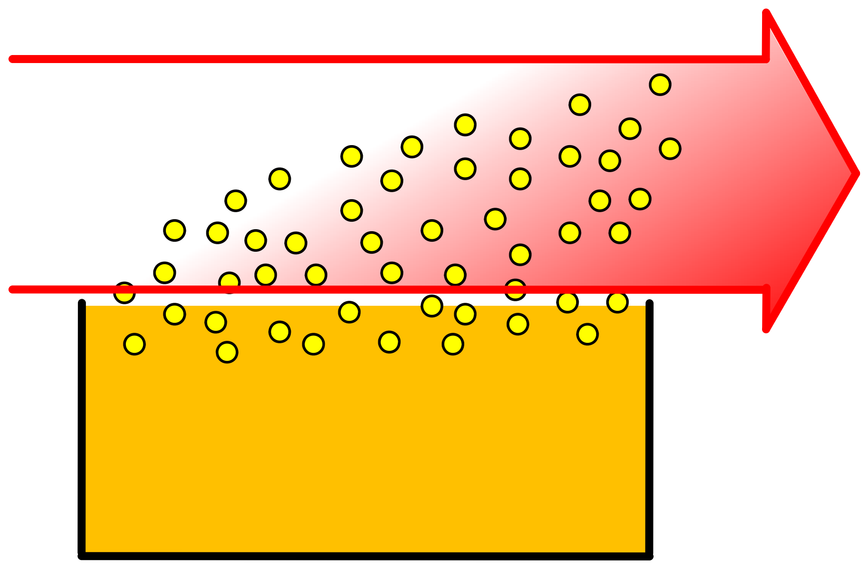
VDI 3880 “Olfactometry – Static sampling”

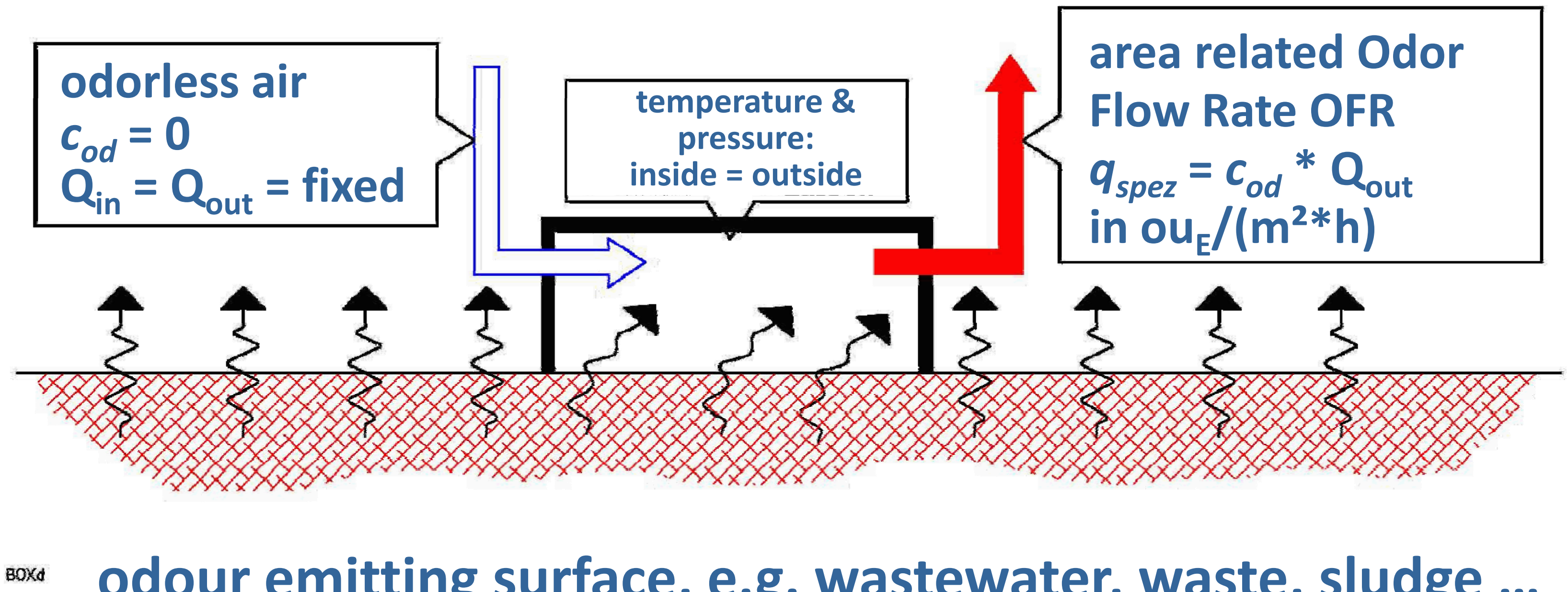
Citerion set by VDI 3880 for use of sampling system on area sources: **30 m³/(m² * h)**



Scheme of a passive area source
flow-through sampling hood to be used



flow-through hood on a passive area source



odour emitting surface, e.g. wastewater, waste, sludge …

sampling with the flow-through sampling hood

- surface covered by box in m^2
- flush air volume flow in m^3/h

→ **flushing rate in $m^3/(m^2 \cdot h)$**

- odour concentration after sampling box in ou_E/m^3

→ **area related odour flow rate q_{spez} in $ou_E/(m^2 \cdot h)$**

- total emitting area in m^2

→ **odour flow rate OFR in ou_E/h**

only the knowledeg of the area related odour flow rate is reasonable and makes comparision possible!

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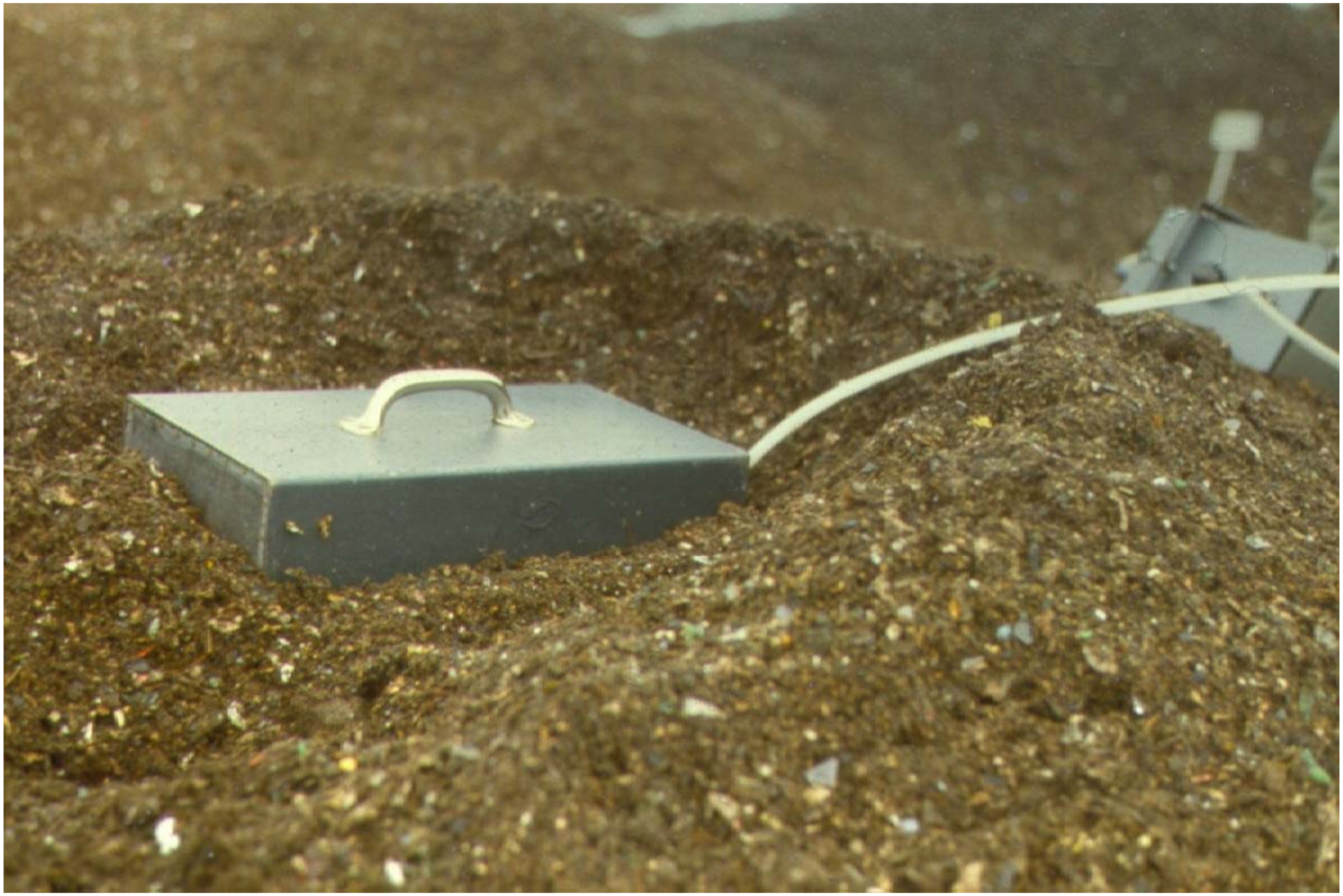
Lemberger box



test of hoods during elaboration of VDI 3880

test of hoods during elaboration of VDI 3880

test of hoods during elaboration of VDI 3880

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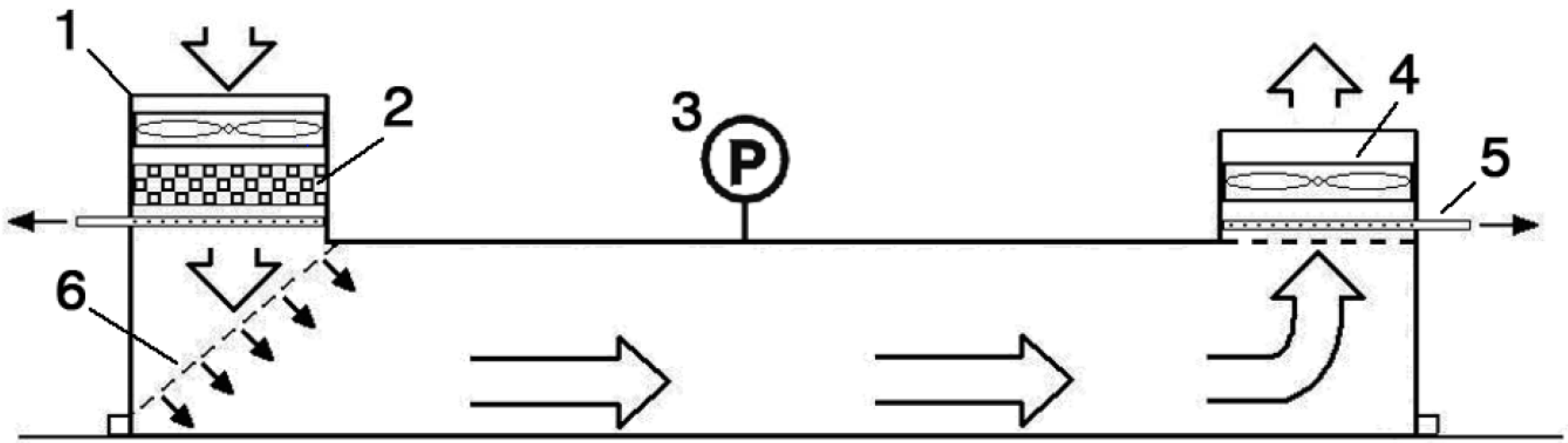
VDI 3880 – hood 1 (no labyrinth)

- final agreement on the type of hood:
  - No labyrinth
  - Shaped like can be seen in sample
  - Dimensions see next slide



1 inlet fan
2 activated carbon filter
3 manometer
4 outlet fan
5 sampling port
6 diffuser plate

(VDI 3880, 2011)

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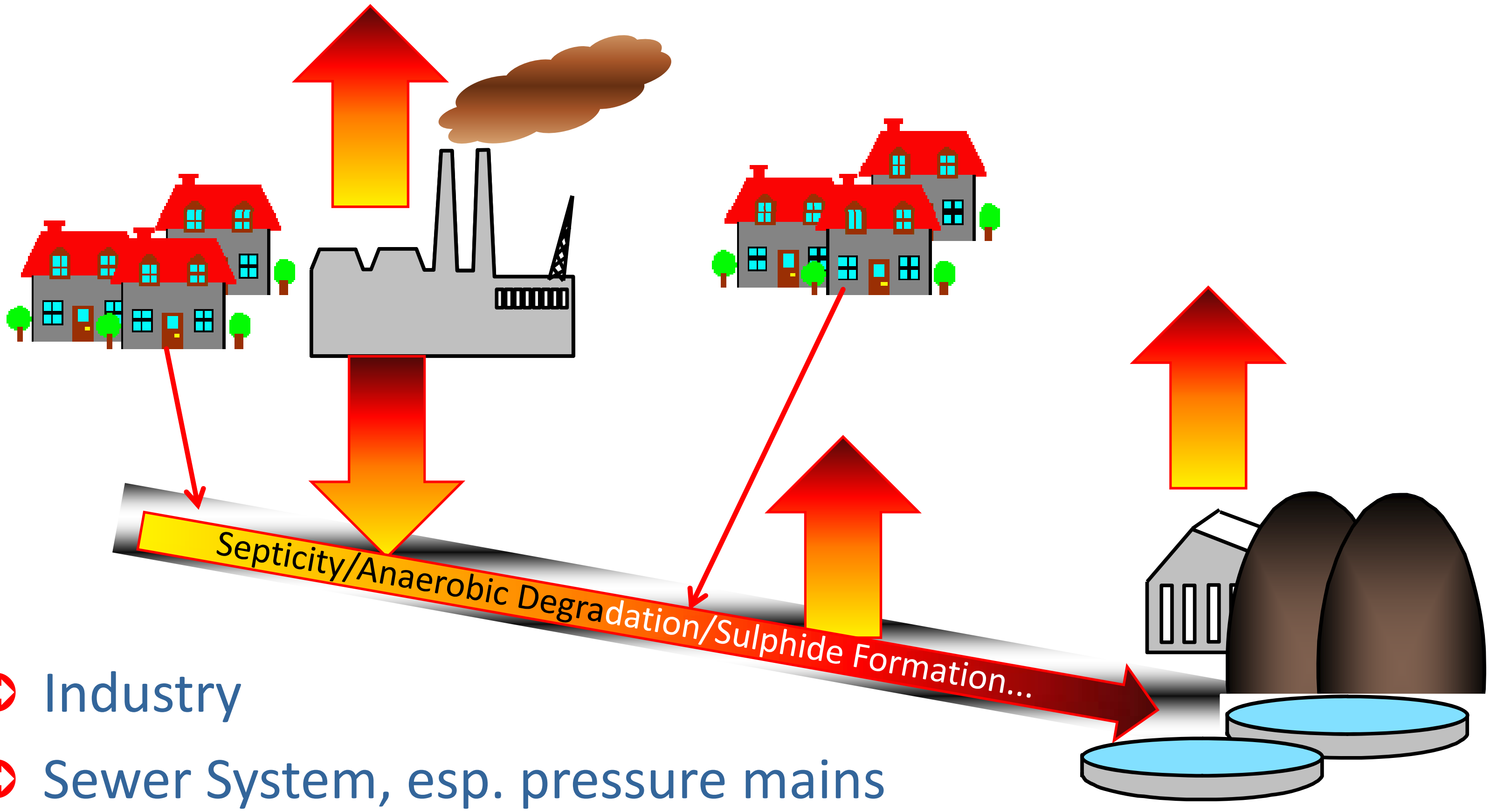
➲ final agreement on the requirements of the hood

inner dimensions of the flow duct L x W x H, in mm	1000 x 500 x 130
surface exposed to flow, in m^2	0,5
mean flow velocity, in cm/s	6,4
contact time of air above surface, in s	15,6
area specific ventilation rate, in $m^3/(m^2*h)$	30

VDI 3885/1

“Olfactometry – Measurement of the odour emission capacity of liquids”

Where does the odour come from?



- Industry
- Sewer System, esp. pressure mains
- Wastewater and Sludge Treatment and Disposal
- In may cases, **liquids** are the original odour sources

The Odour Emission Capacity OEC of a liquid is the total amount of odorants present in that liquid that can be stripped from this liquid under standardized conditions.

[Frechen and Köster, Wat.Sci.Tech.,1998]

It is given in European odour units per cubic meter of liquid.

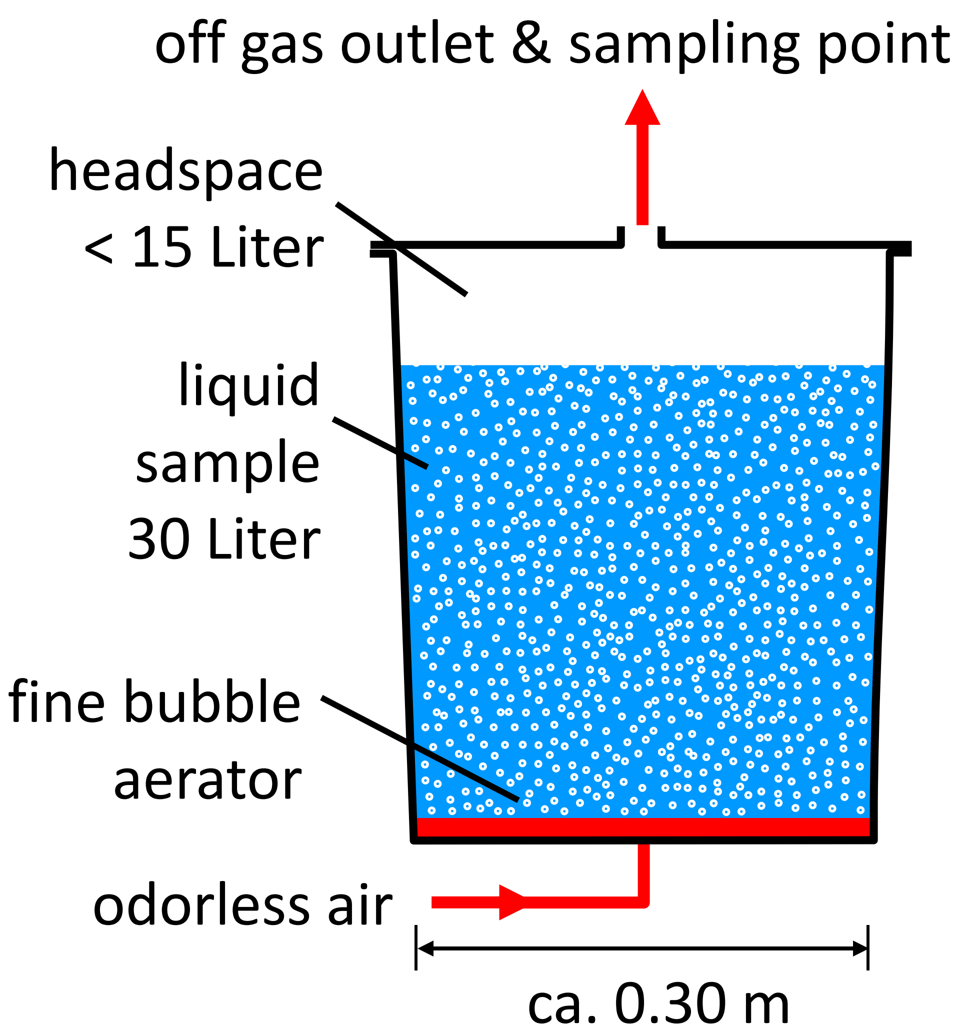
Its unit is ou_E/m^3_{liquid}

The OEC method is covered by the **new VDI guideline 3885/1**. It will be published 2014

As we strip off the odorants into **air samples**, **quantification** can be done by the standard olfactometric method according to CEN 13725:2003

Also, different analytical procedures can be applied to the stripped air, resulting in **Emission Capacities** of the substances analysed

OEC test reactor



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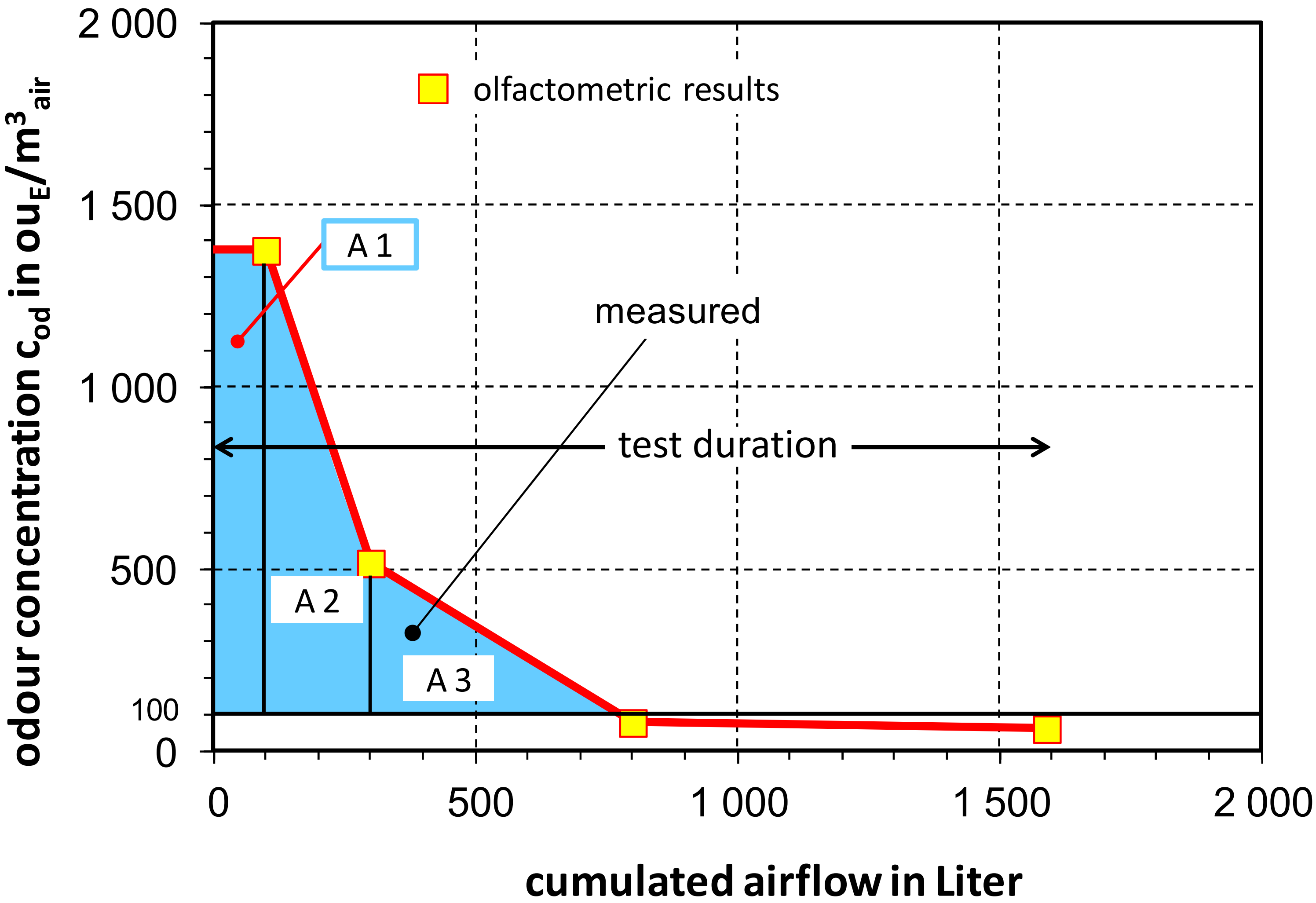
evaluation – type a



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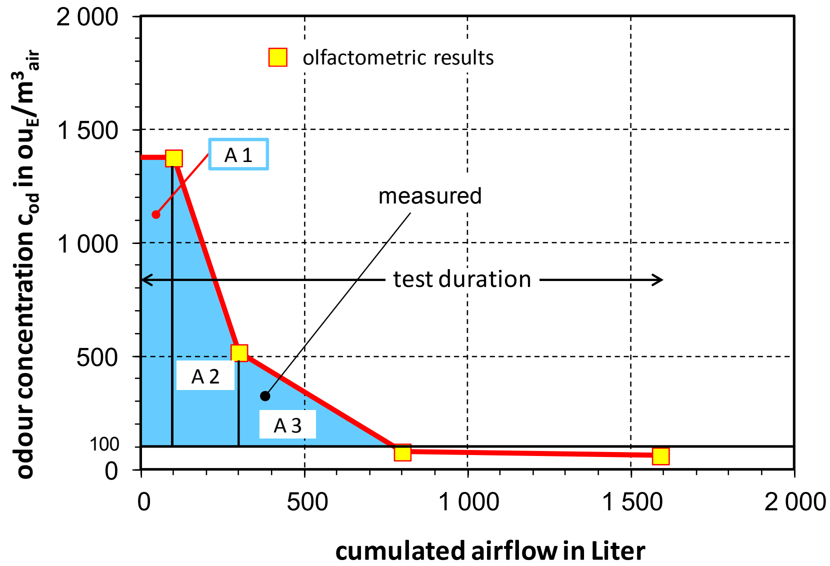
evaluation – type a

- the measurement curve does fall below the „lower integration limit LIL“ of c_{od} = 100 ou_E/m^3_{air}
- the **OEC$_{total}$** equals the **OEC$_{measured}$** (blue area) and is the area (integral) between the LIL (horizontal line at c_{od} = 100 ou_E/m^3_{air}) and the measurement curve
- the **OEC$_{total}$** is calculated as the sum of areas A1 to A3



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2nd + 3rd SOU in operation at the Bottrop Sewer

Purpose:

- ✓ avoid overdosing
- ✓ avoid underdosing

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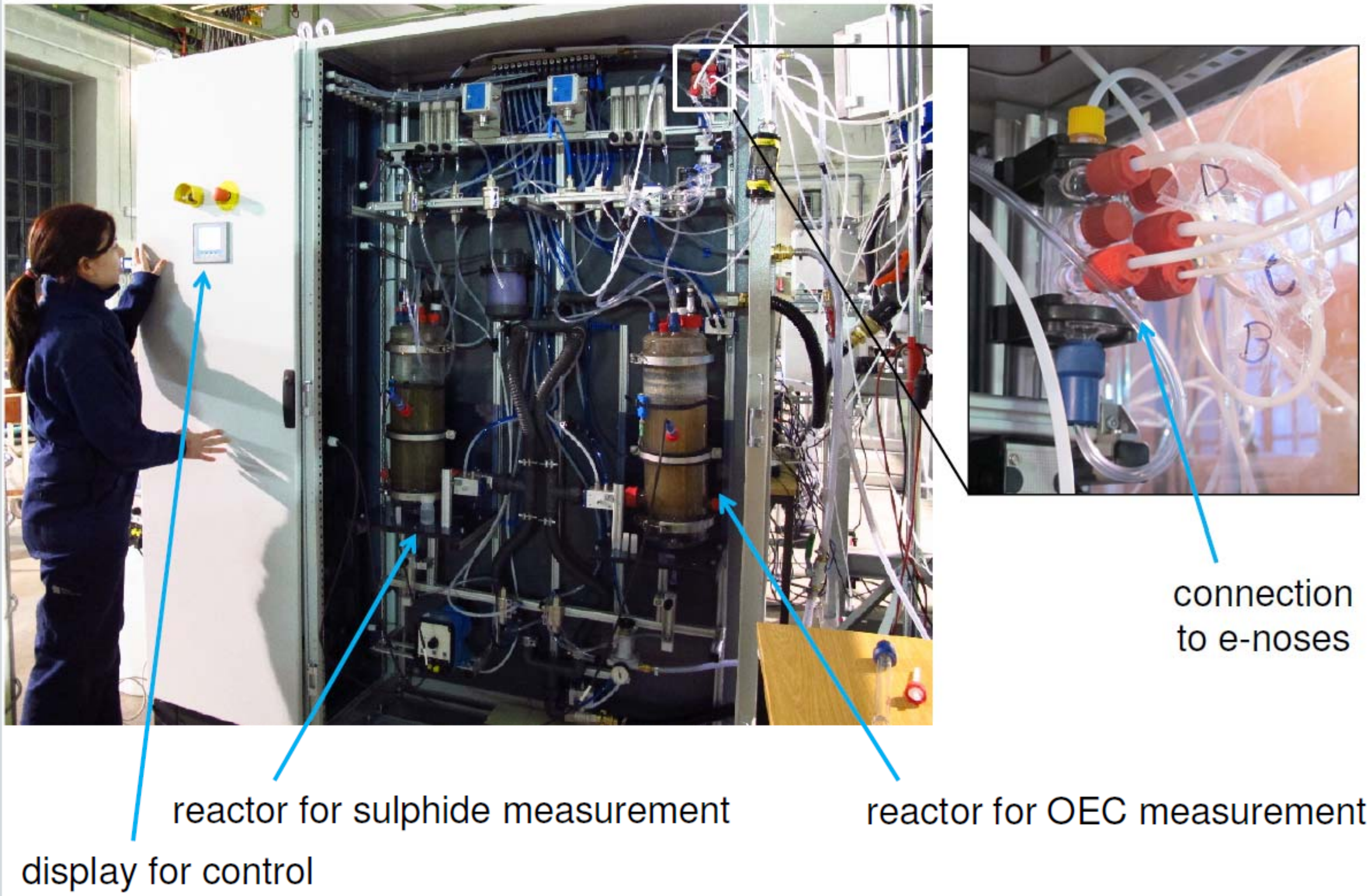
Research-SOU in operation in Berlin at BWB+KWB

ODOC ARTN SE



2

KOMPETENZZENTRUM Wasser Berlin

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electronic noses

- The perfect eNose would be able to measure the REAL odour concentration. This means that a mathematical model exists that converts 4 to 10 sensors readings into one number (the REAL odour concentration)
- To establish such a model, it is necessary to do **parallel measurements** with
  - eNose
  - olfactometer
- **The more parallel readings** (the bigger the mathematical sample size), the better the mathematical model can be

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DESEE' datapool:

- 5 eNose brands
- 3 olfactometry labs
- Different origins of odours

project	eNose	period	olfactomery	origin of odour	number
Vienna	A	2005	Lab 1	wastewater	382
Vienna	B	2005	Lab 1	wastewater	156
Hilter	A	4/2008 - 5/2008	Lab 2	wastewater	40
emscher sewer	A	1/2007 - 1/2008	Lab 2	wastewater	150
Biofilter	C	2009	Lab 2	wastewater	12
OEC with wastewater	A,A	2010	Lab 2	wastewater	88
safety research part 1	*A,A*	*2007*		*drugs/explosives*	*(8)*
safety research part 2	*A,A*	*2010*		*drugs/explosives*	*(40)*
lab test	*C*	*2009*		*hydrogen sulphide*	*(20)*
Verden	A,A	2010/2011	Lab 3	wastewater	110
Aachen	A,A	2011	Lab 3	wastewater	156
Berlin	A,B,D,E	2011/2012	Lab 3	wastewater	1429
				total with olfactometry:	**2.523**

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Possible sources of problems and errors

- Sampling
- Uncertainty of olfactometric measurement
- The eNose itself
- The odour's nature
- The mathematical evaluation

Possible sources of problems and errors

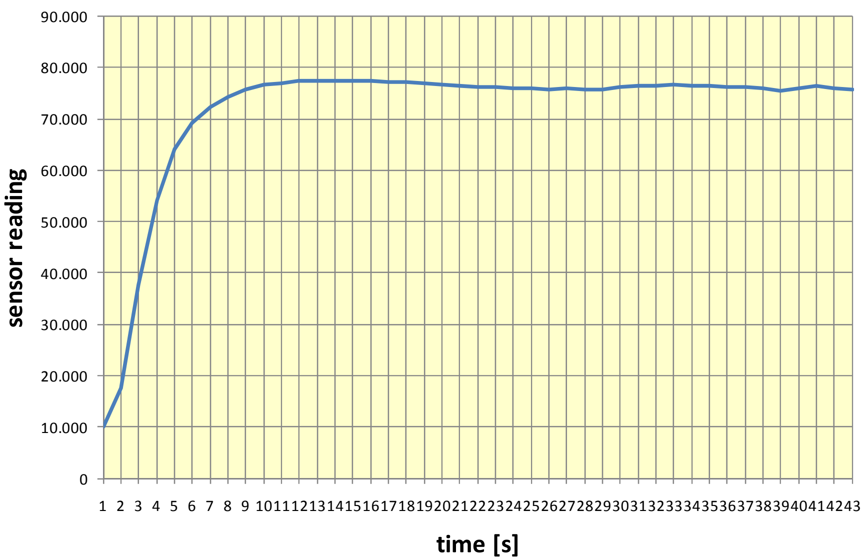
- Uncertainty of olfactometric measurement
  - It has to be differentiated between THE REAL ODOUR and THE ODOUR MEASURED BY OLFACTOMETRY
  - Olfactometry measurement has an error itself. According to Boeker (2005) this can be estimated to be 50%.
  - This means: if an eNose perfectly explains the odour as measured by olfactometry, (claimed by some vendors of eNoses: $R^2 = 1$!!), the model has an error of 50%!

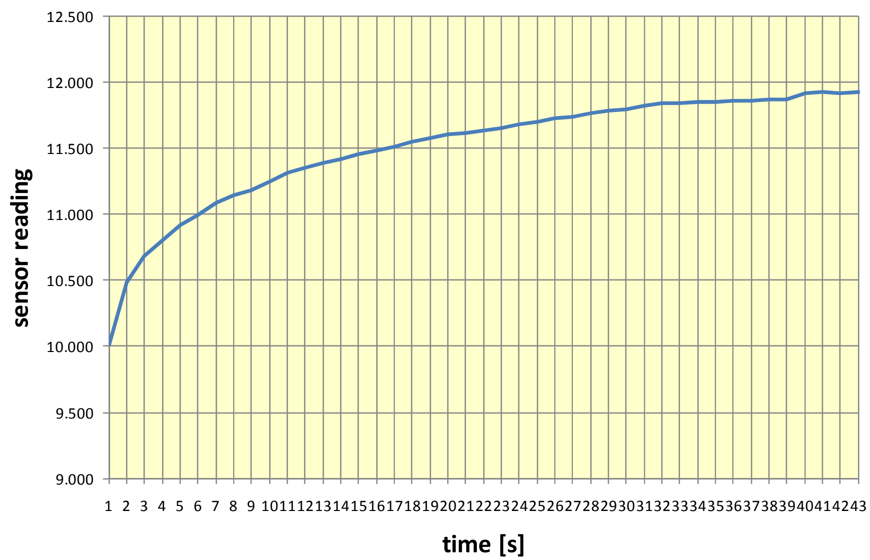
Possible sources of problems and errors

The eNose itself

t_{90}-time

- no information provided by the manufacturers
- t_{90}-time differs from sensor to sensor
- t_{90}-time differs from odour to odour
- Some sensor signals do not converge to a final value at all – then there is no t_{90}-time at all …





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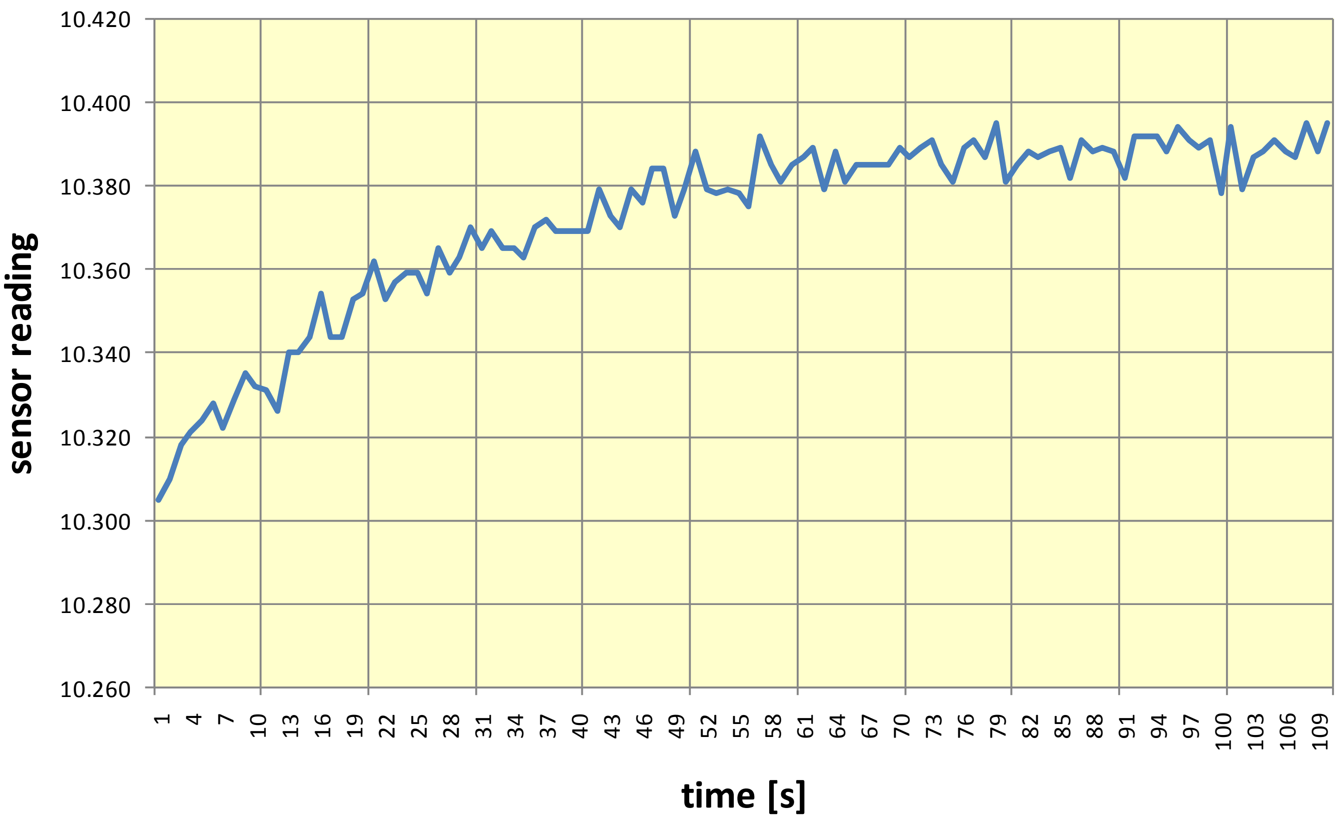
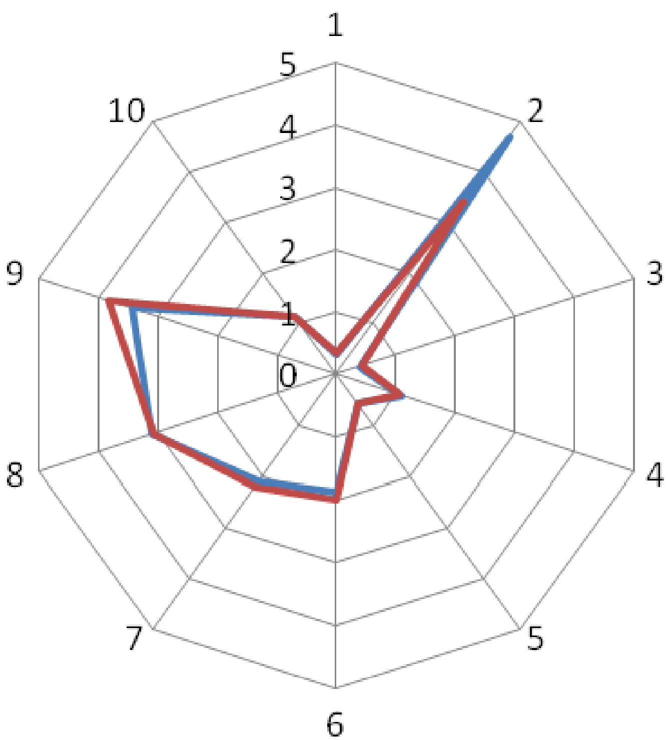
Possible sources of problems and errors

- The eNose itself
  - t_{90}-time
  - oscillating readings – mean used



Possible sources of problems and errors

- The eNose itself
  - t_{90}-time
  - oscillating readings – mean used
  - do 2 eNoses of the same type and age deliver the same readings?



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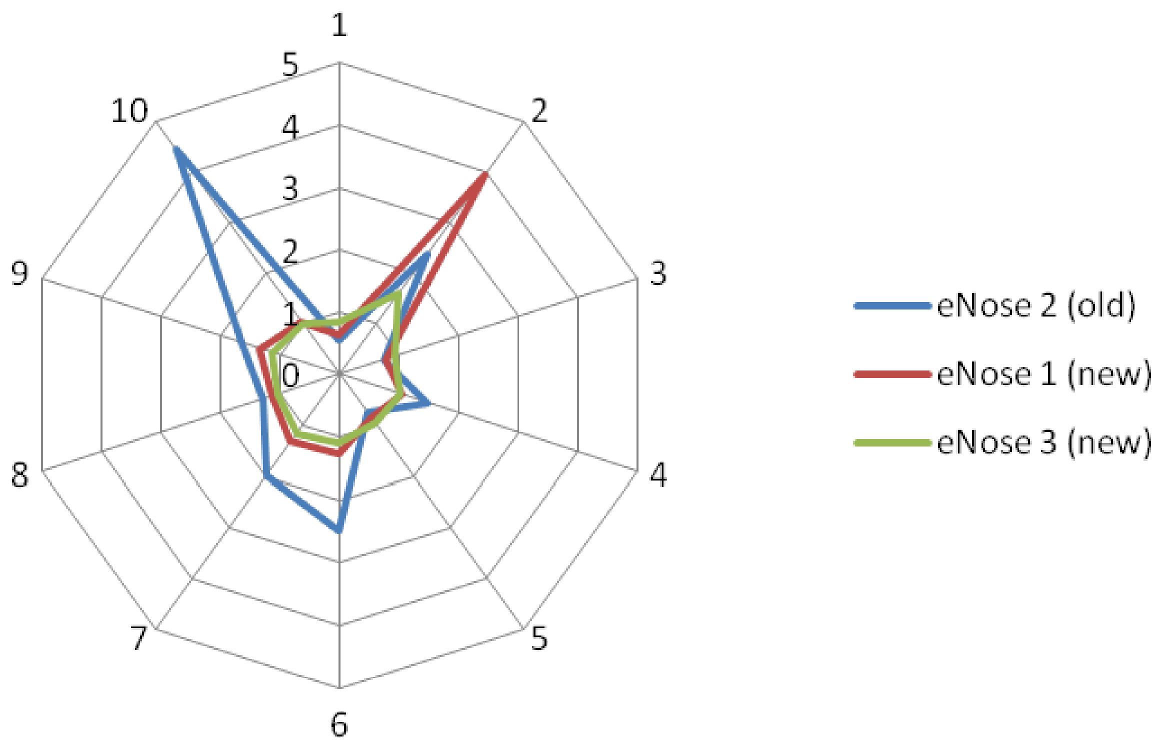
Possible sources of problems and errors

➲ The eNose itself

- t_{90}-time
- oscillating readings – mean used
- do 2 eNoses of the same type and age deliver the same readings?
- aging of sensors



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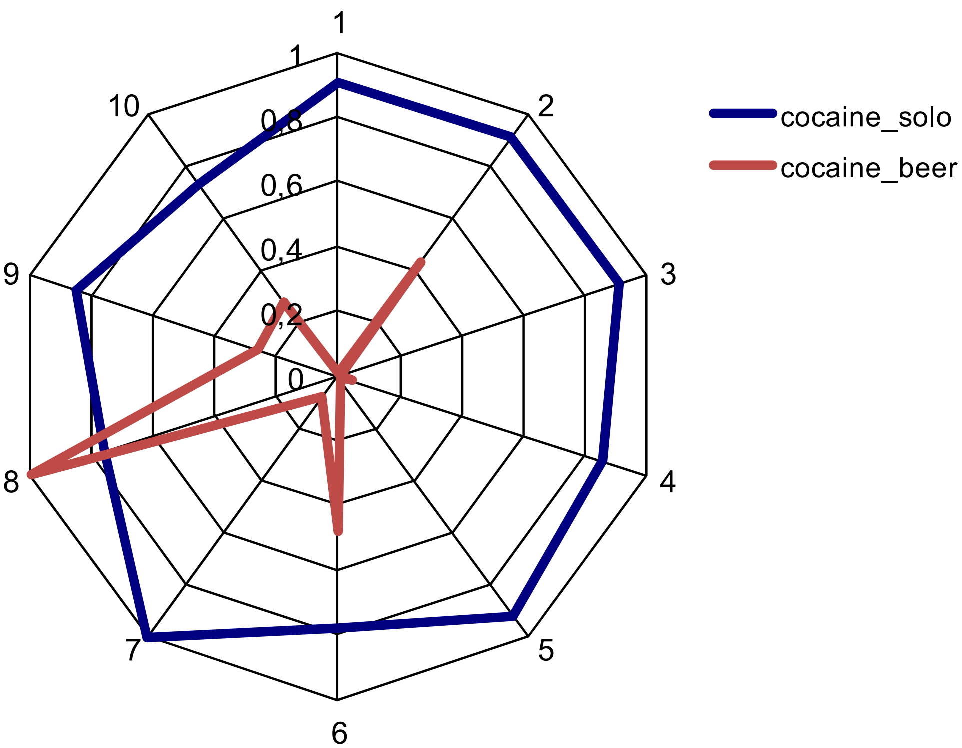
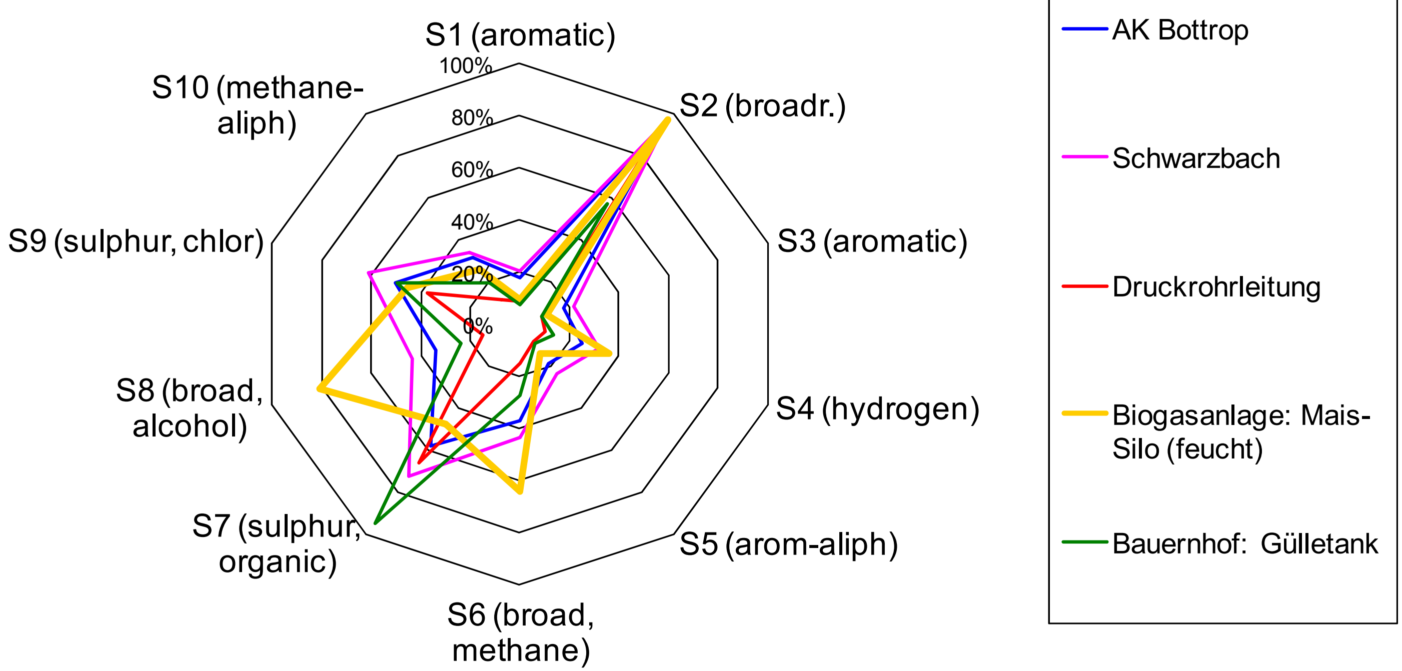
Possible sources of problems and errors

- The odour's nature
  - Although already well established in several (specific) industrial processes, eNoses still have problems with the very varying composition of odours – e.g. wastewater odours, but also others

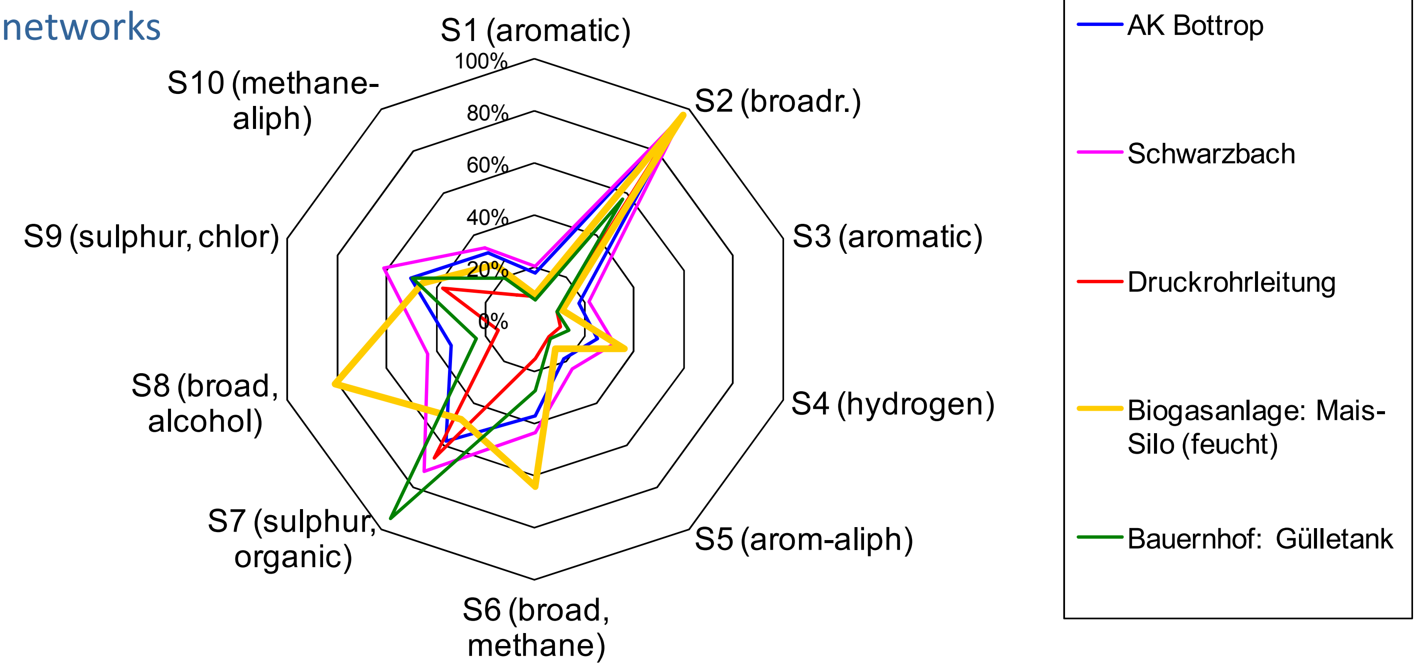


- **Mathematical evaluation** of the raw data is the **crucial step** in eNose usage. Methods may aim for
  - **Qualification** (“which kind of smell is that”)



Legende: S1…S10 sind die Sensoren des Multisensormessgerätes

- **Mathematical evaluation** of the raw data is the crucial step in eNose usage. Methods may aim for
  - **Qualification** ("which kind of smell is that")
    - Pattern recognition with
      - Configuration frequency analysis
      - Shape analysis
      - Neural networks



Legende: S1...S10 sind die Sensoren des Multisensormessgerätes

- **Mathematical evaluation** of the raw data is the crucial step in eNose usage. Methods may aim for
  - **Qualification** ("which kind of smell is that")
    - Pattern recognition with
      - Configuration frequency analysis
      - Shape analysis
      - Neural networks
  - **Quantification** ("ou_E/m^3")
    - Partial Least Square PLS
    - Linear Regression
    - Nonlinear Regression
    - Logistic Regression (below or above a given limit value)
    - Neural networks (able to achieve nearly perfect explanation, but ability for prediction is crucial, see below!)
- in this presentation, we deal with quantification

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Simple mathematical errors (example)

- selection of data used for evaluation:
  - The smaller the mathematical data sample size, the bigger the possibility to get a deterministic model. In the case of ten sensors and eleven unknown coefficients in a model one always gets around 100% correct classification, if using eleven measurements or less.

- Most important with mathematical models is to distinct between
  - **explanation** (done in nearly 99% of cases) and
  - **prediction** capabilities determination by **data splitting**!
- If vendors claim that their eNose is capable of measuring odour with a correlation coefficient of near 1, they usually talk about **explanation** of historical data (ou_E/m^3 measured using olfactometry vs. ou_E/m^3 calculated from the eNose raw data)
- There are no vendors known that really check for prediction abilities. If so, they should testify that they
  - used the bootstrap-procedure: derive a model for **explanation** basing on part (e.g. 50%) of the data (training data) (this is the explanation part, possibly with high correlation coefficients), and
  - applied this model to the other part of the data for **prediction**.
- Correlation coefficients near 1 for **prediction** are not achievable as set out before (REAL odour vs OLFACTOMETRIC odour)

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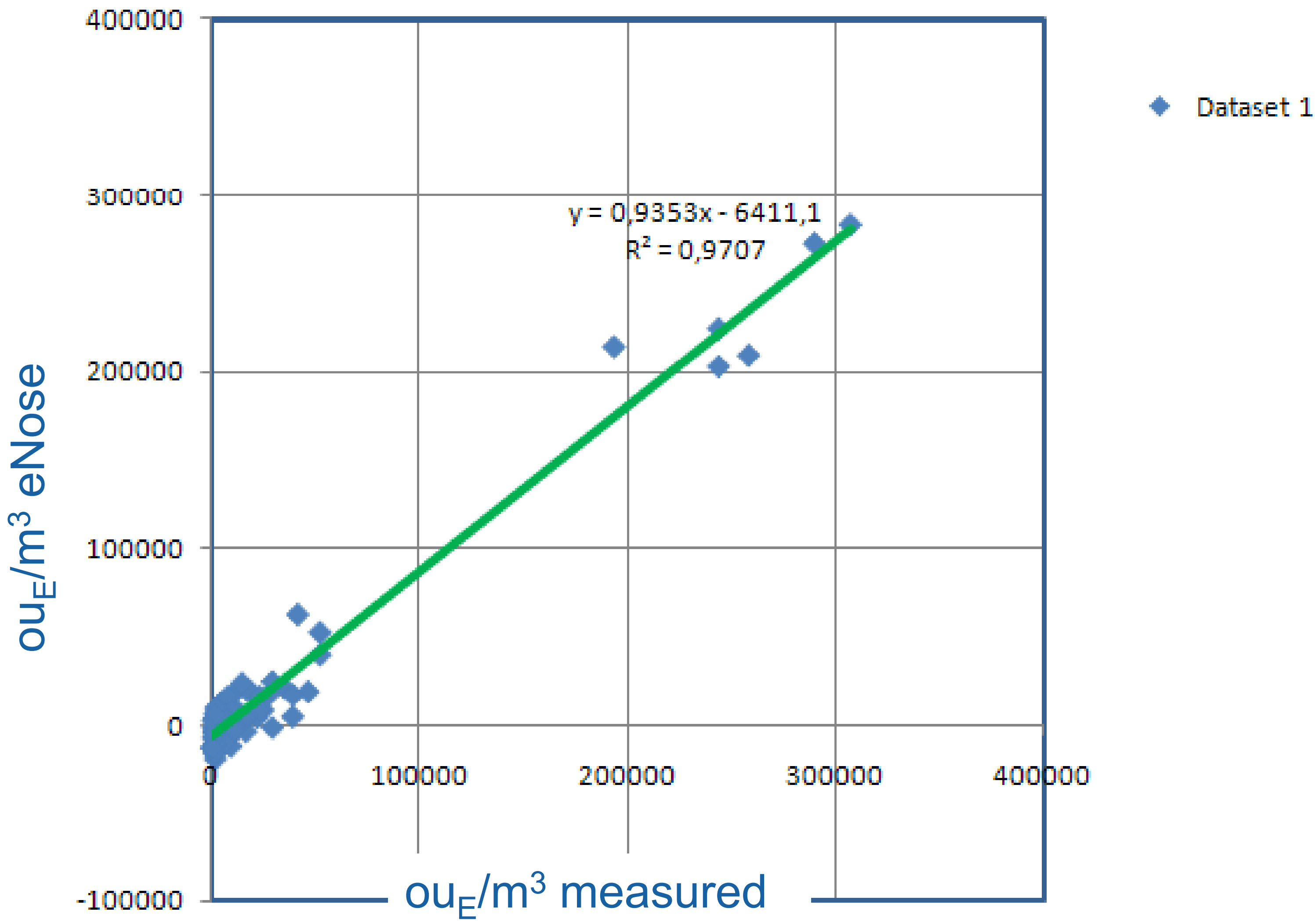
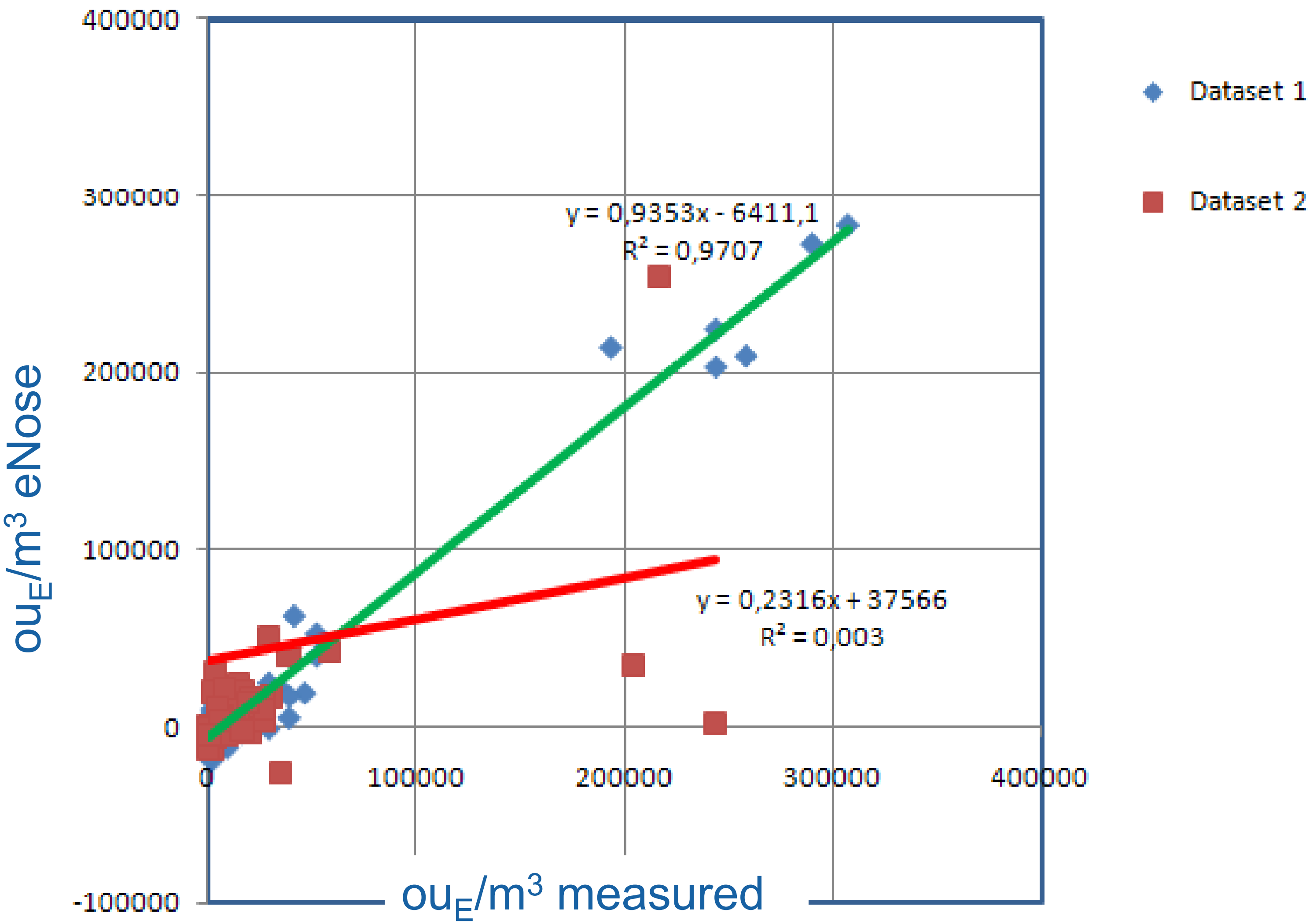
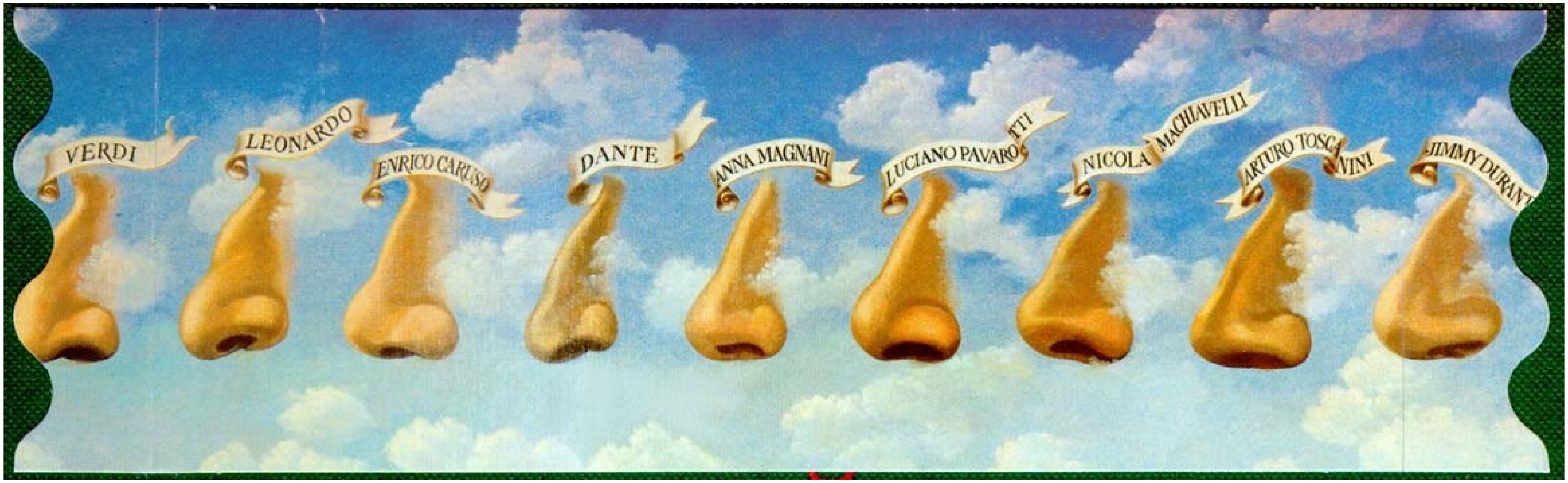
Correlation using model derived from training data (dataset 1) (explanation)




400000
300000
200000
100000
0
-100000
0
100000
200000
300000
400000
y = 0,9353x - 6411,1
R² = 0,9707
y = 0,2316x + 37566
R² = 0,003
Dataset 1
Dataset 2
ouE/m3 eNose
ouE/m3 measured

Thank you for your patient attention !



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