Chapter 7: Odour Treatment

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Should we care about odour contamination in WWTPs?

EL MUNDO

Residents start Demostrations against malodours in Getafe

GETAFE.- El barrio de Perales del Río, de la localidad de Getafe, se ha convertido en el «triángulo de la porquería» de la región madrileña. Su **cercanía a cuatro depuradoras**, la incineradora de Valdemingoméz y secaderos de lodos han convertido esta populosa barriada en una **zona prácticamente irrespirable.**

Noticias de Guipuzcoa

Residents affected by Loiola WWTP Malodours from Definitive Closure demand their 03-10-2006

Vecinos de los barrios de Loiola, Txomin Enea, Martutene, Zorroaga e Intxaurrondo han exigido la "paralización total" de la actividad de la Estación Depuradora de Aguas Residuales (EDAR) de Loiola hasta "que se adopten todas las correcciones necesarias para que no afecte a la salud de las personas y no altere en absoluto la calidad del aire".....

EL PAIS

20 residents lock themself in Vigo WWTP

10/11/2007

...Los vecinos exigen que el Ayuntamiento de Vigo adopte una **Solution for the malodour problem** que tienen que soportar. Dieciséis vecinos tuvieron que ser realojados en hoteles a causa de una gri... digestor de la planta, la enésima a... estas instalaciones.....

Definitely…..

EL PAIS

A FILTER THAT POLLUTES
El Puerto - 22/04/2002

Tras su entrada en funcionamiento, en 1994, llegaron las primeras señales de alerta por **problems derived from malodours**. *Aún hoy éste es* **one the identity signs of the facility……**

EL MUNDO

The New WWTPs will increase Malodours in San Gabriel and Benalúa

El estudio ambiental de la planta que dará servicio a Rabasa, el Pau 1 y San Vicente advierte sobre vertidos que **generate malodours and social complaints.** La nueva depuradora de l'Alacantí Sur que se prevé construir en Fontcaler contará ……

ABC

Canal de Castilla promises to Remove Malodours from Móstoles WWTPs

MÓSTOLES. 11-1-2002

La reunión, a la que acudieron además varios representantes vecinales y la concejal de Medio Ambiente de la localidad, Ángela Álvarez, sirvió para que los afectados trasladasen a los responsables del Canal su annoyance due to malodours que, en su opinión produce la depuradora de El Soto.

Odour Contamination

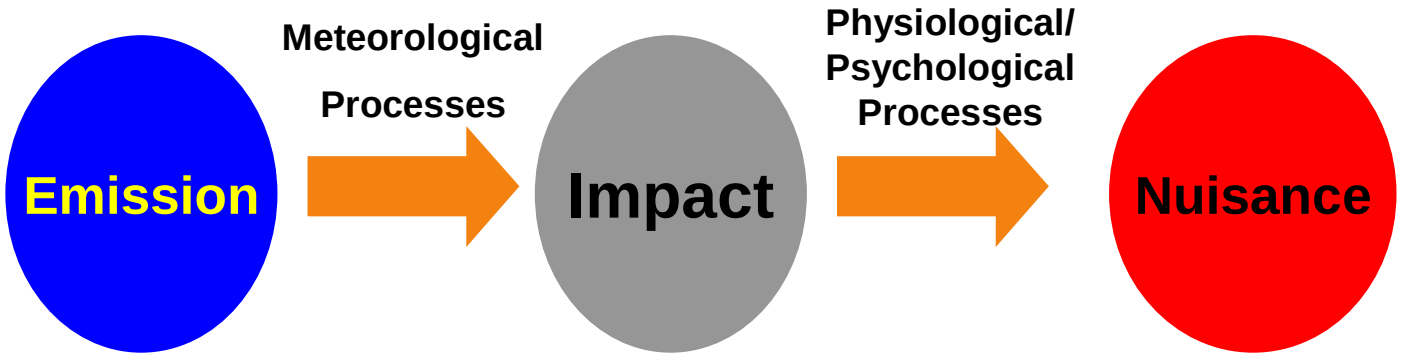
Gaseous emissions have traditionally received less attention than solid or liquid ones

Lower Risk for human health and natural ecosystems

According to the WHO: *"Health is a state of complete physical, mental and social well-being and not merely the absence of disease"*

Odour Pollution affects human health indirectly and negatively

Odour Contamination



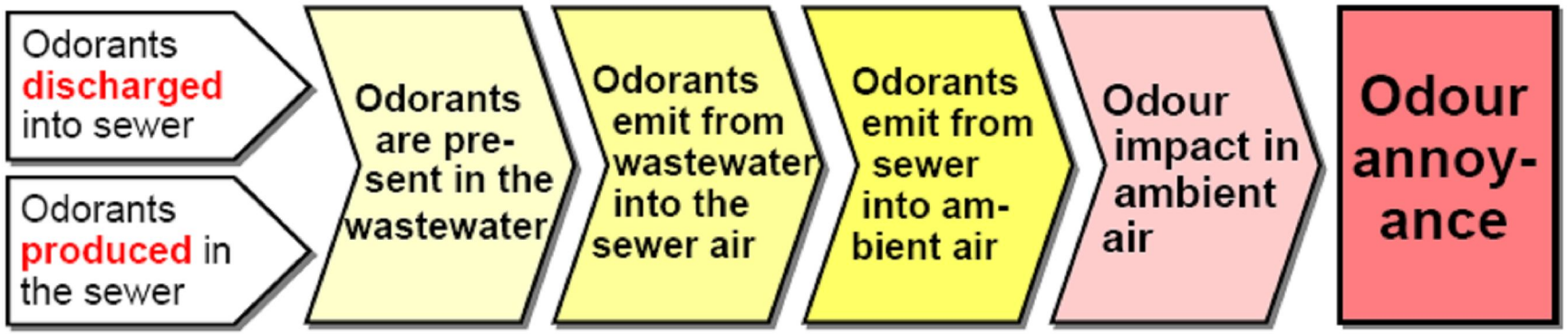
The main factors responsible for this process are rather complex:

- ODOUR CHARACTERISTICS (Intensity, hedonic tone, type of odour, concentration, annoyance potential)
- TURBULENCE OR ATMOSPHERIC STABILITY (emission dilution)
- DEGREE OF EXPOSURE (duration, frequency, period of the day/week/year)
- RECEPTOR CHARACTERISTICS (Rural vs Urban areas, history of exposure, association with health risk

Odour Contamination in WWTPs

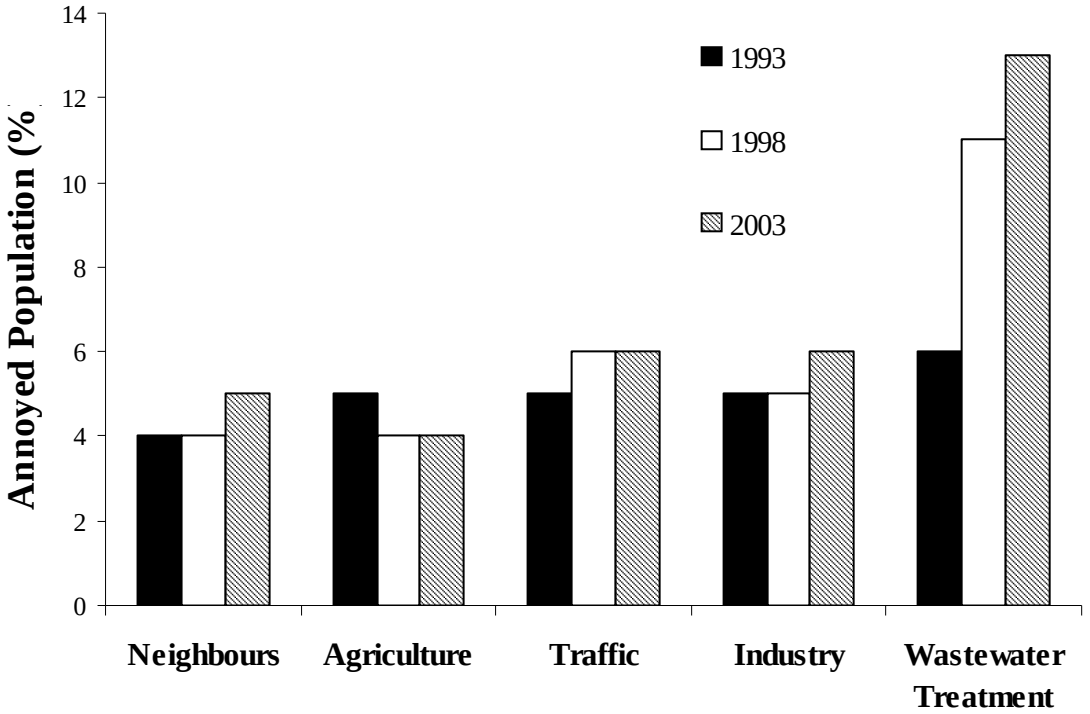
- Origin of odour nuisance in WWTPs: Psychological Interpretation
- Malodours are associated with organic matter decomposition

Example: odour annoyance generation from sewers



Odour Contamination in WWTPs

According to a recent survey with 2000 people interviewed in the Netherlands between 1993 & 2003, WWTPs were the most serious cause of nuisance

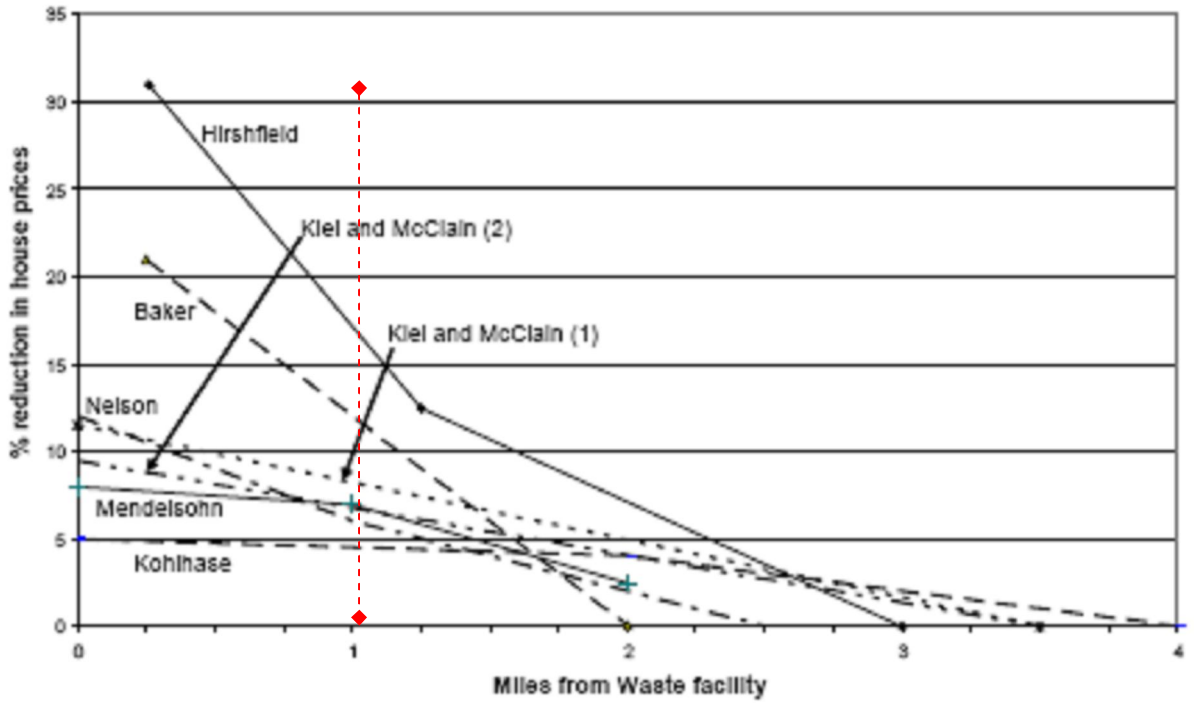


(Franssen et al 2004)

Odour Contamination in WWTPs

Effects of odour contamination in property value

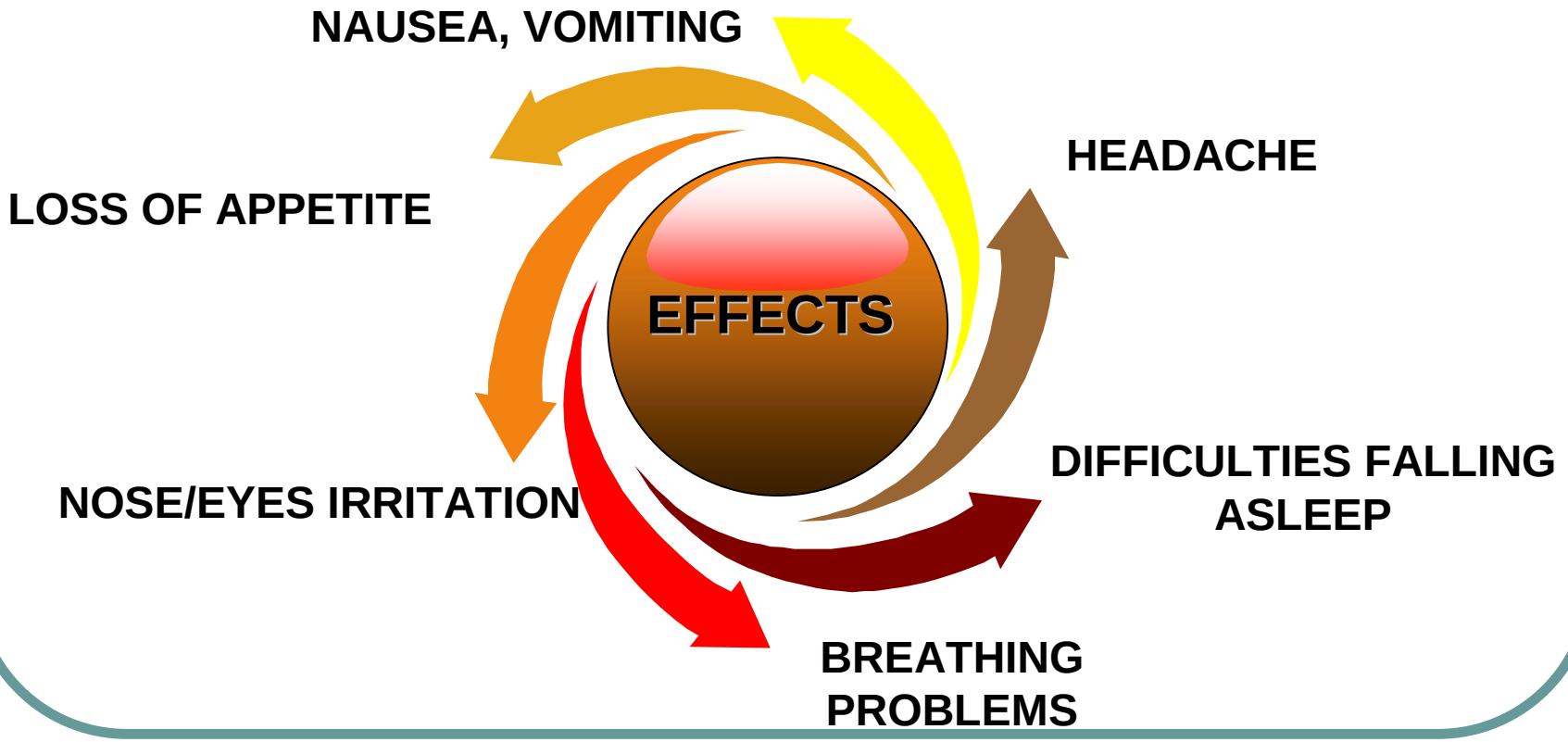
Figure 4 Reduction in house prices around odour sources (redrawn from the study of Brisson and Pearce, 1992)



Reductions in house prices from 4 to 17 % within a 1-mile radius!!!

Which are the effects of odour contamination by WWTP emissions on humans?

"Health is a state of complete physical, mental and social well-being and not merely the absence of disease"



Why this sudden increase in the number of complaints ?

More than half the complaints received by public administrations worldwide are due to Malodours!!!!

A MORE STRICT ENVIRONMENTAL LEGISLATION

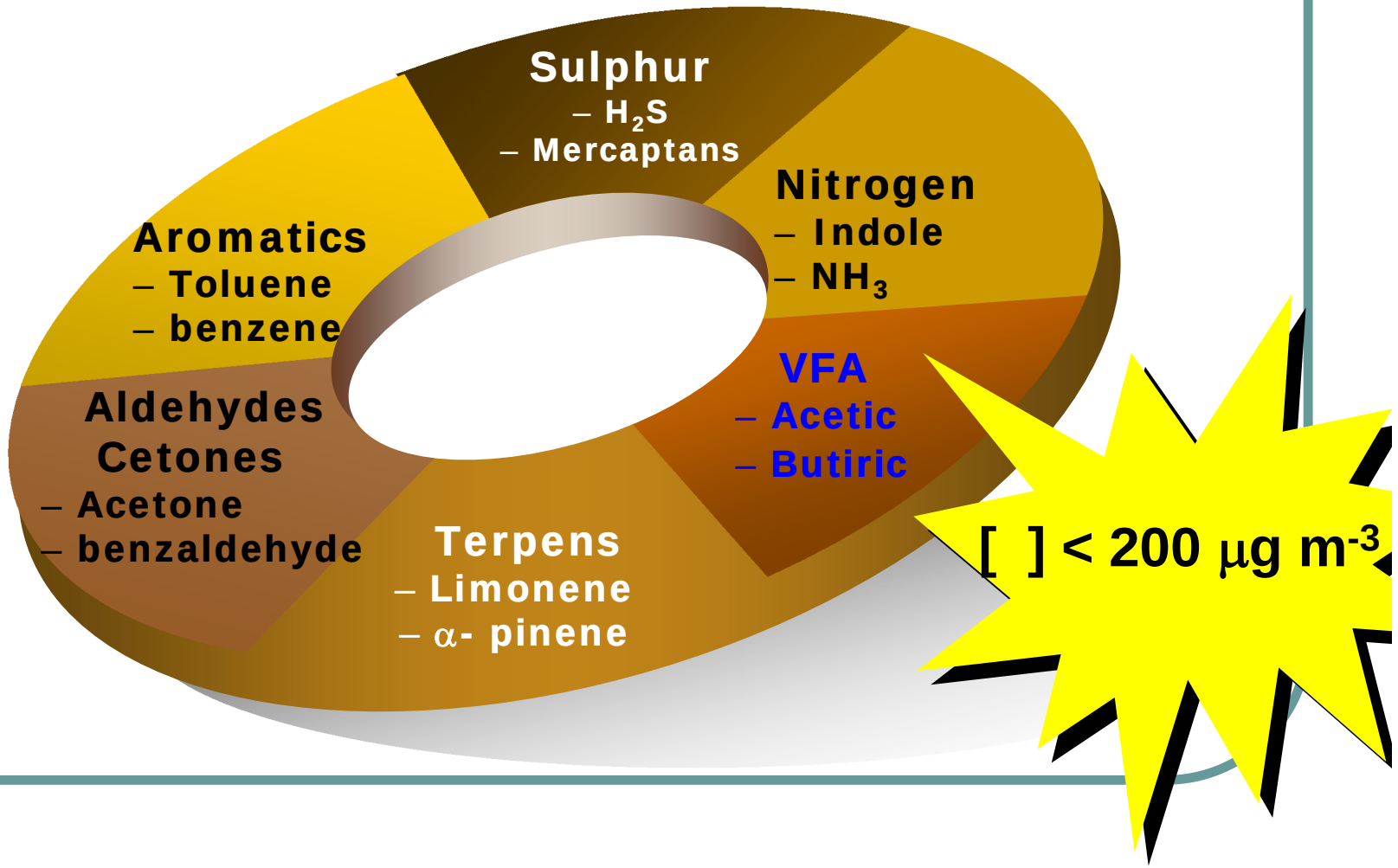
INCREASE IN THE NUMBER OF RESIDENTIAL AREAS CLOSE TO WWTPs

HIGHER CONCERN OF PEOPLE REGARDING THEIR RIGHTS

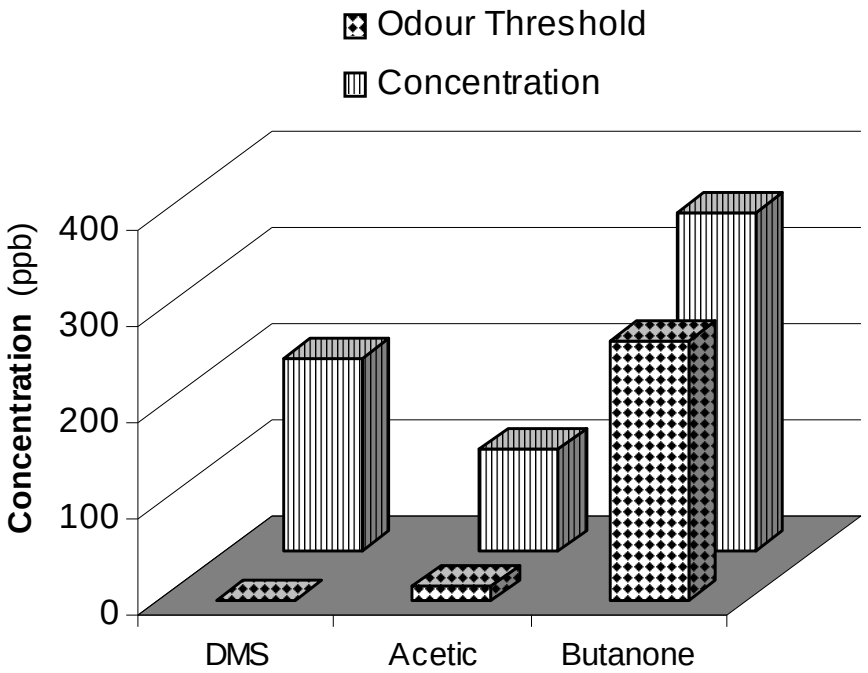
INCREASE IN PUBLIC EXPECTATIONS OF PRIVATE WATER COMPANY DUTIES

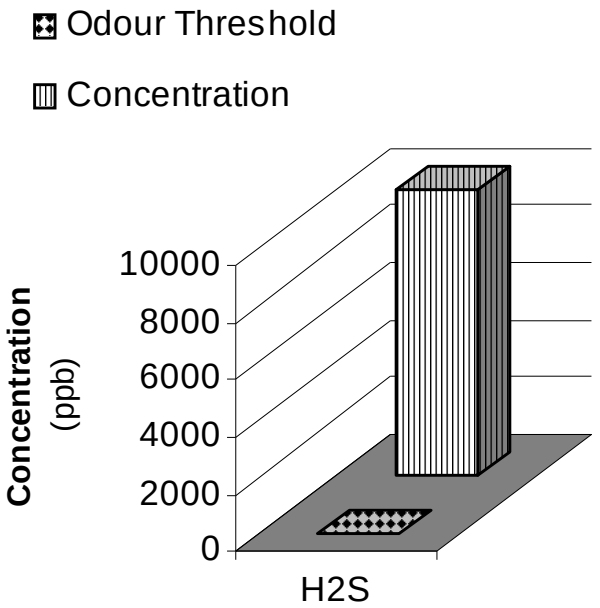
..SO..WHAT ARE THESE EMISSIONS COMPOSED OF?

COMPLEX MIXTURES AT CONCENTRATIONS 6-7 ORDERS OF MAGNITUDE LOWER THAN THOSE FOUND IN WASTEWATER!!!



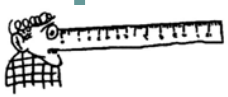
..AND EVEN AT SUCH LOW CONCENTRATIONS, DO THEY GENERATE ANNOYANCE?





Odour Thresholds are still lower!!!!

…and how do we measure odours???



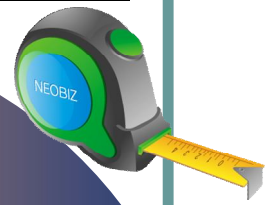
Sensorial Measurements

Response of the olfactory system

Subjective and costly

Dynamic olfactometry

Analytical Measurements



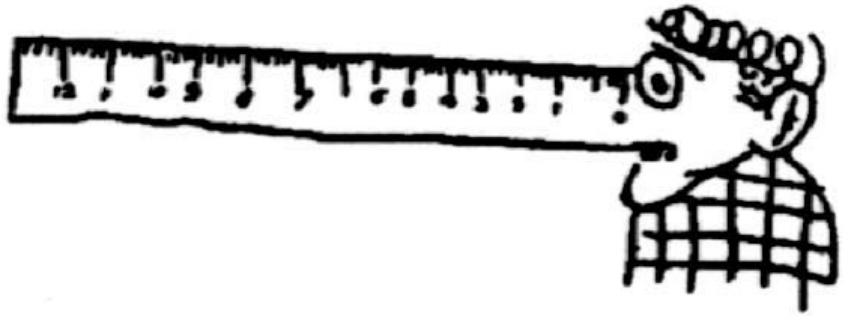
Identification and quantification of the chemical composition

Reproducible and Objective

GC-MS/GC-FID/Jerome

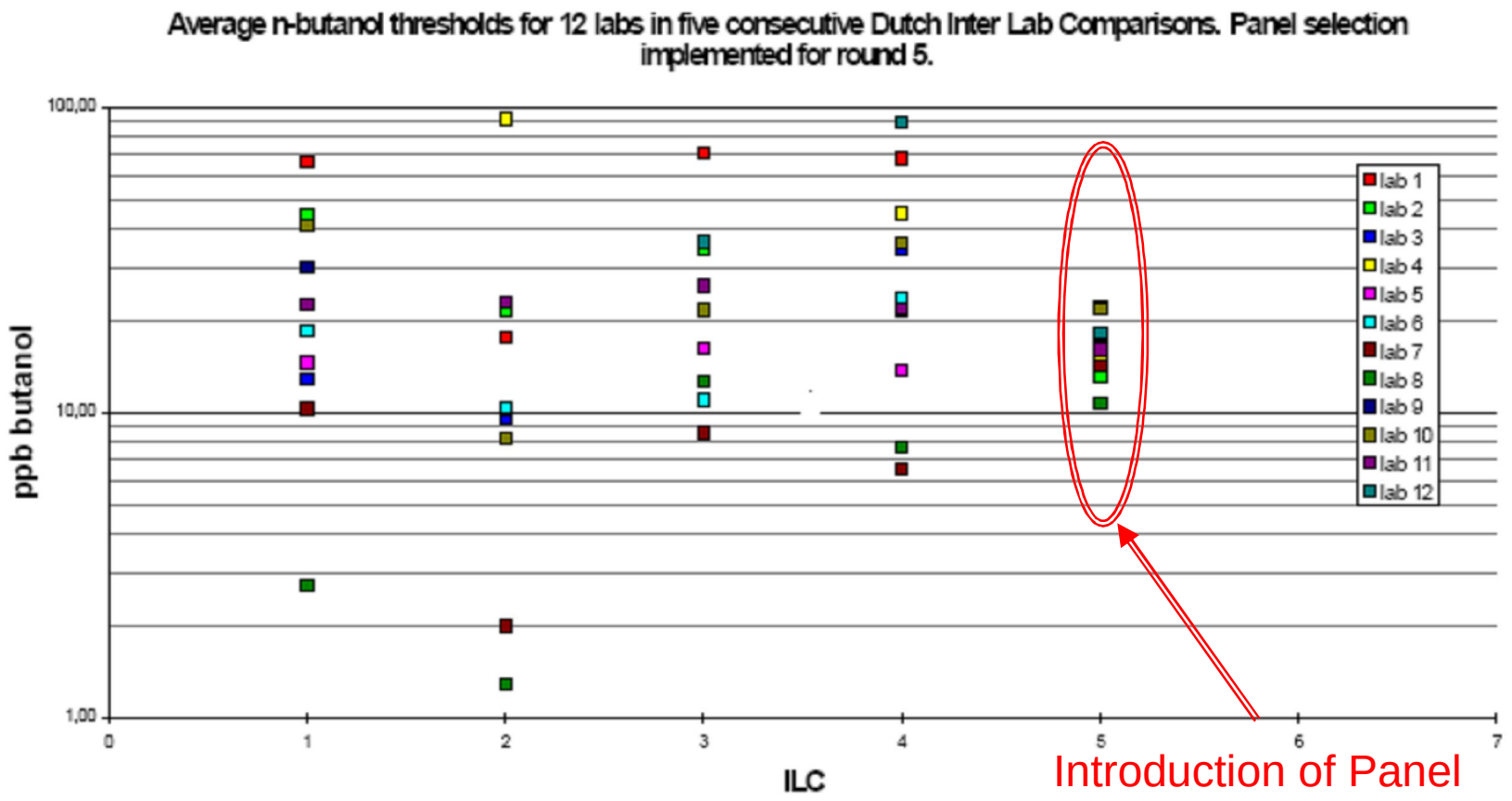
Sensorial Measurements: Olfactometry

- Olfactometry: Measurement of the response of a panellist to a olfactory stimulus. The nose as detector.



- Olfactometry measurements must be: Objective and Reproducible
- Olfactometry is based on Odour Threshold Detection
- Odour Threshold constitutes the basis of olfactometry but varies with people: previous exposure, background odours, olfactory sensitivity.

Sensorial Measurements: Olfactometry



Sensorial Measurements: Olfactometry

ODOURNET: www.odournet.com

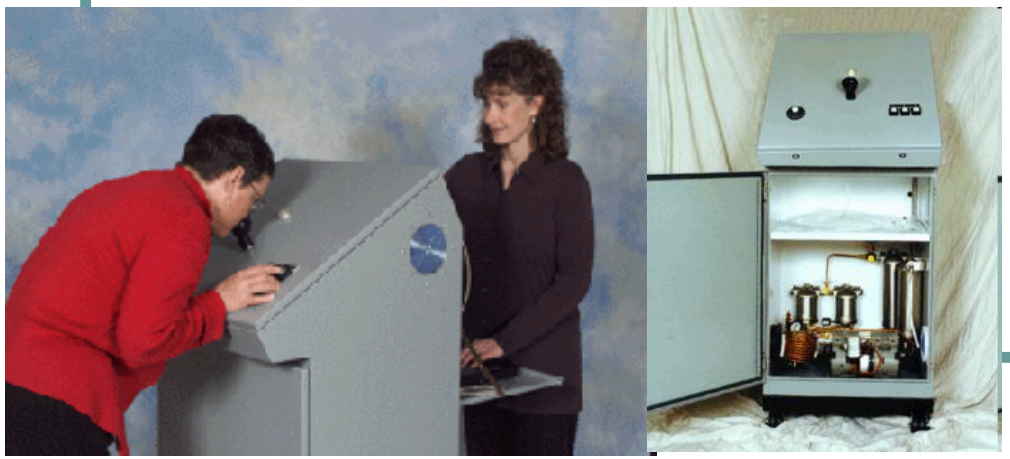
ECOMA GmbH: www.ecoma.de

ST. CROIX SENSORY INC: www.fivesenses.com

UNIVERSITY OF NEW SOUTH WALES (Australia): http://www.cwwt.unsw.edu.au/

ENVIRONODOUR: http://www.environodour.com.au/

Yes/No olfactometer



Forced-Choice olfactometry

Sensorial Measurements: Olfactometry

Odour Wheels: Qualitative Description of odorous samples

11 Odour Descriptors associated with a Chemical

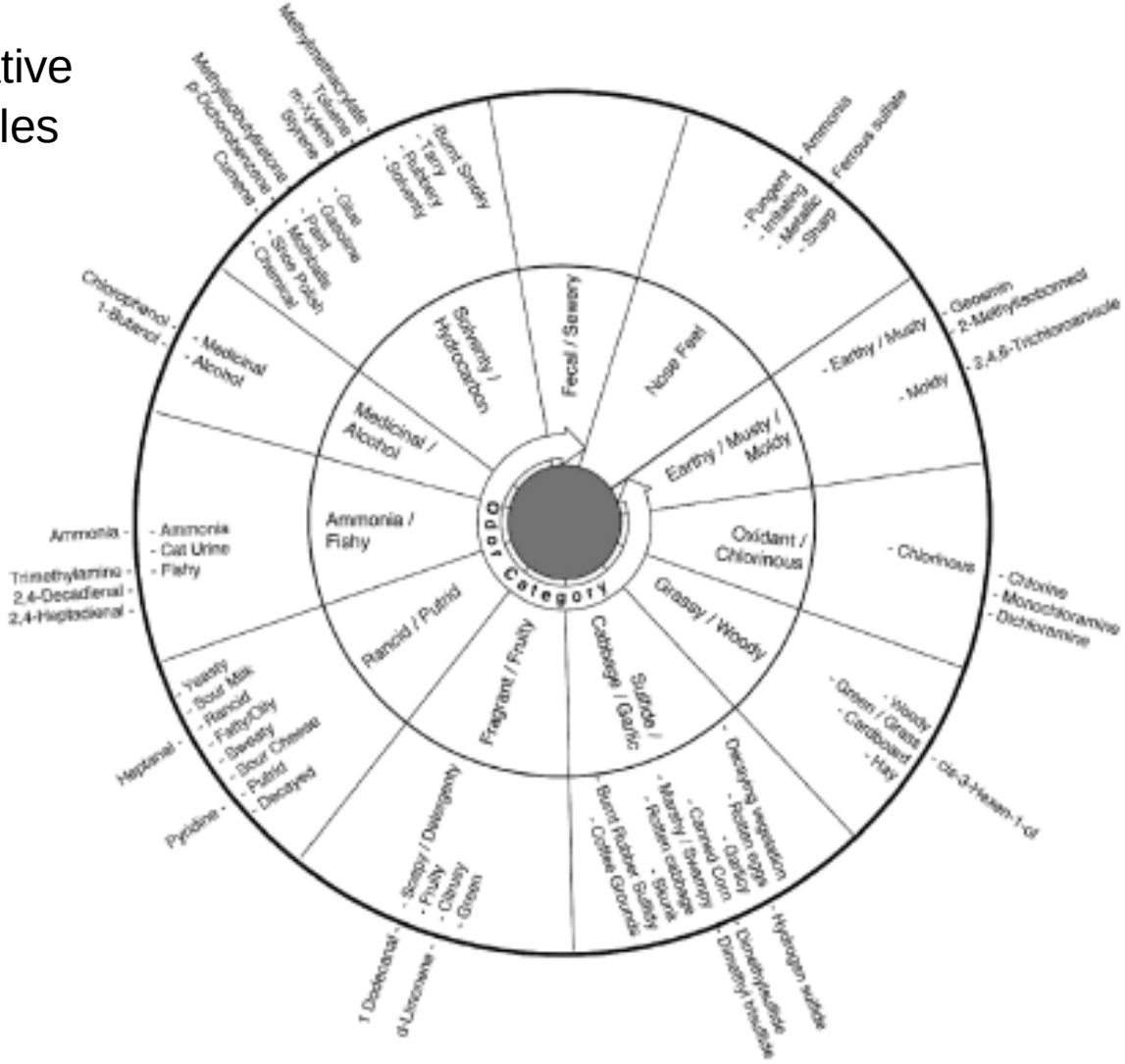


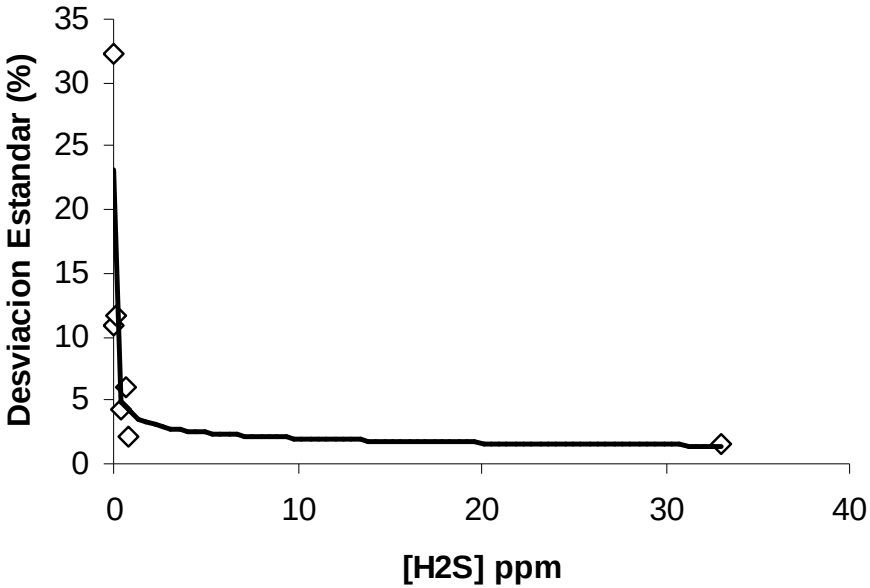
Figure 1 Wastewater odour wheel

Measuring odours: H_2S as surrogate

Most common method: **Gold Film Resistance Detector**. The change in resistance in the gold film is proportional to the H_2S concentration adsorbed

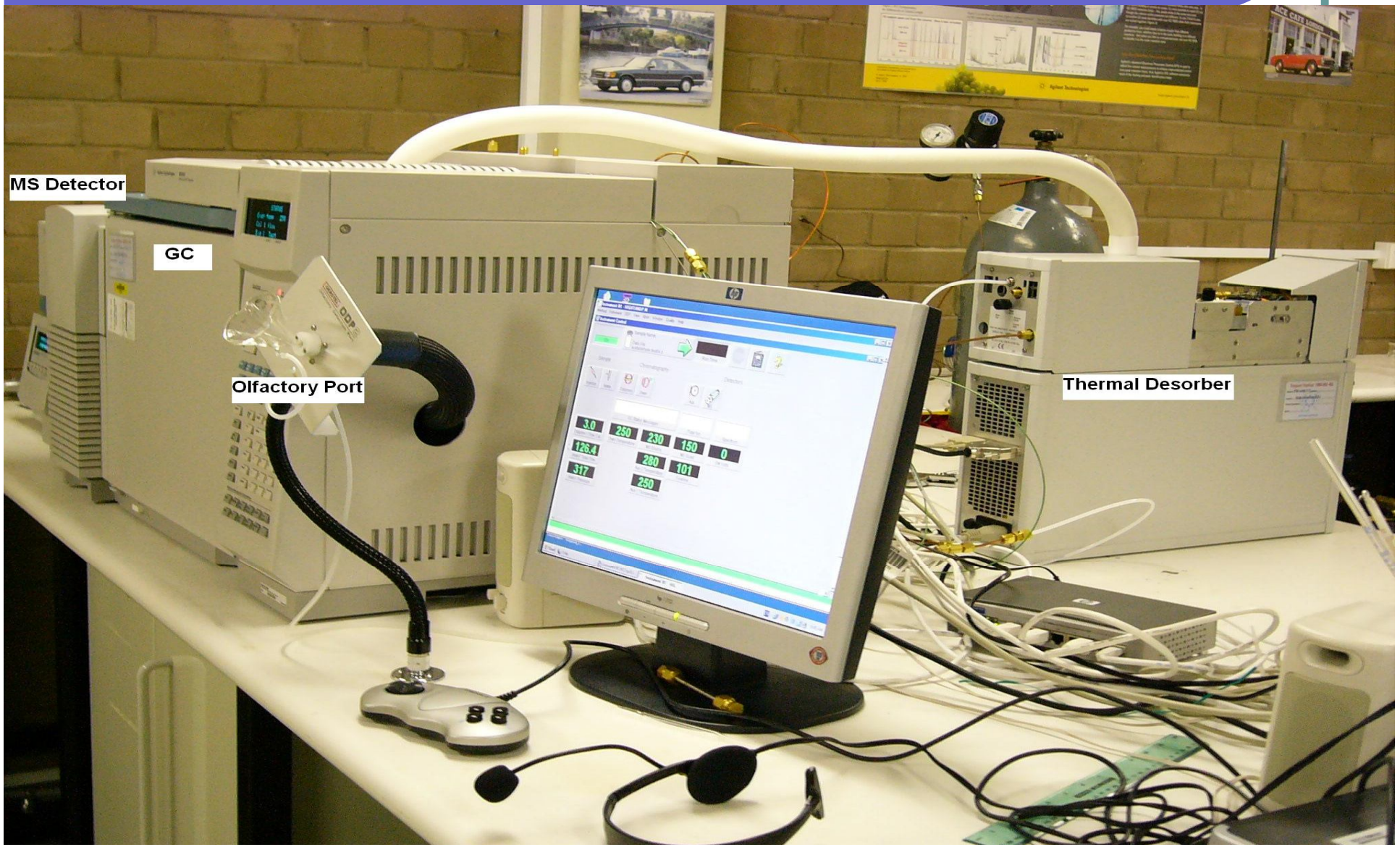
Commercially available: JEROME 631-X (Arizona Instruments, USA). Range 2 ppb - 50 ppm at reasonable precision and accuracy

www.azic.com



30 s per reading!!

GC-MS Measurements



GC-MS Measurements

Contaminants are trapped into an adsorbent material

Contaminants are then desorbed and analyzed by GC

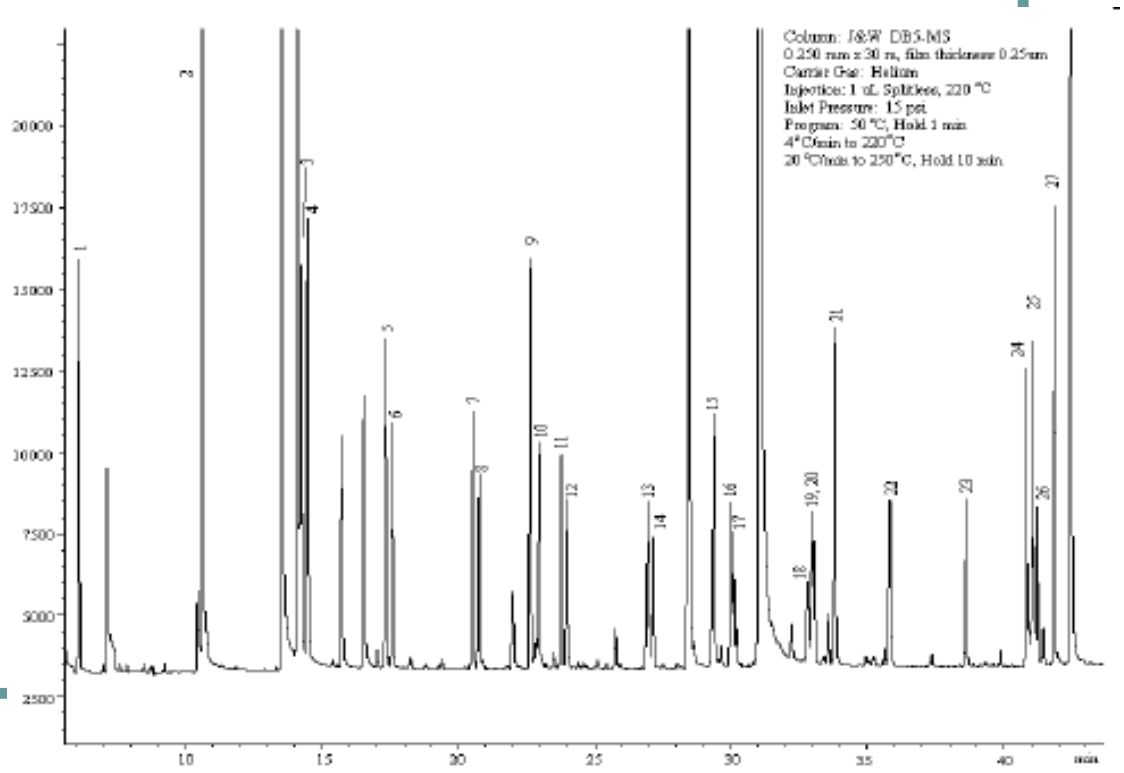
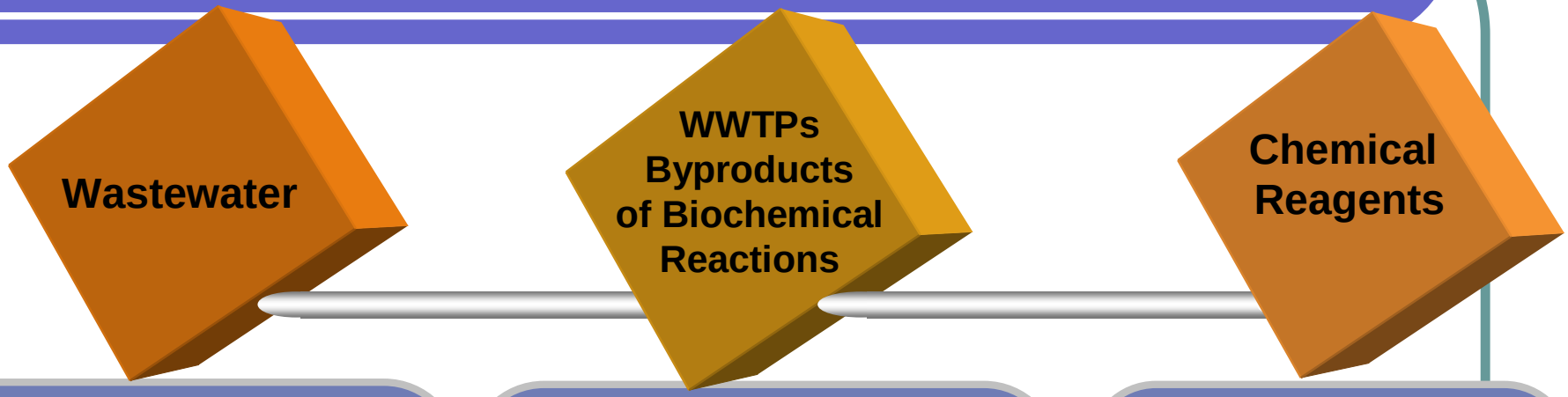


Figure 1

…How and where do these malodours originate??



Industrial and Domestic discharges

Hydrocarbons

Indole, NH_3

Anaerobic Decomposition of organic matter in Sewers

H_2S, VFA

In the absence of O_2 & NO_3^-

- *Sulphate Reduction*

H_2S

- Fermentation Processes

VFA

Cetones

Sulphur Compounds

Chemicals employed during Treatment

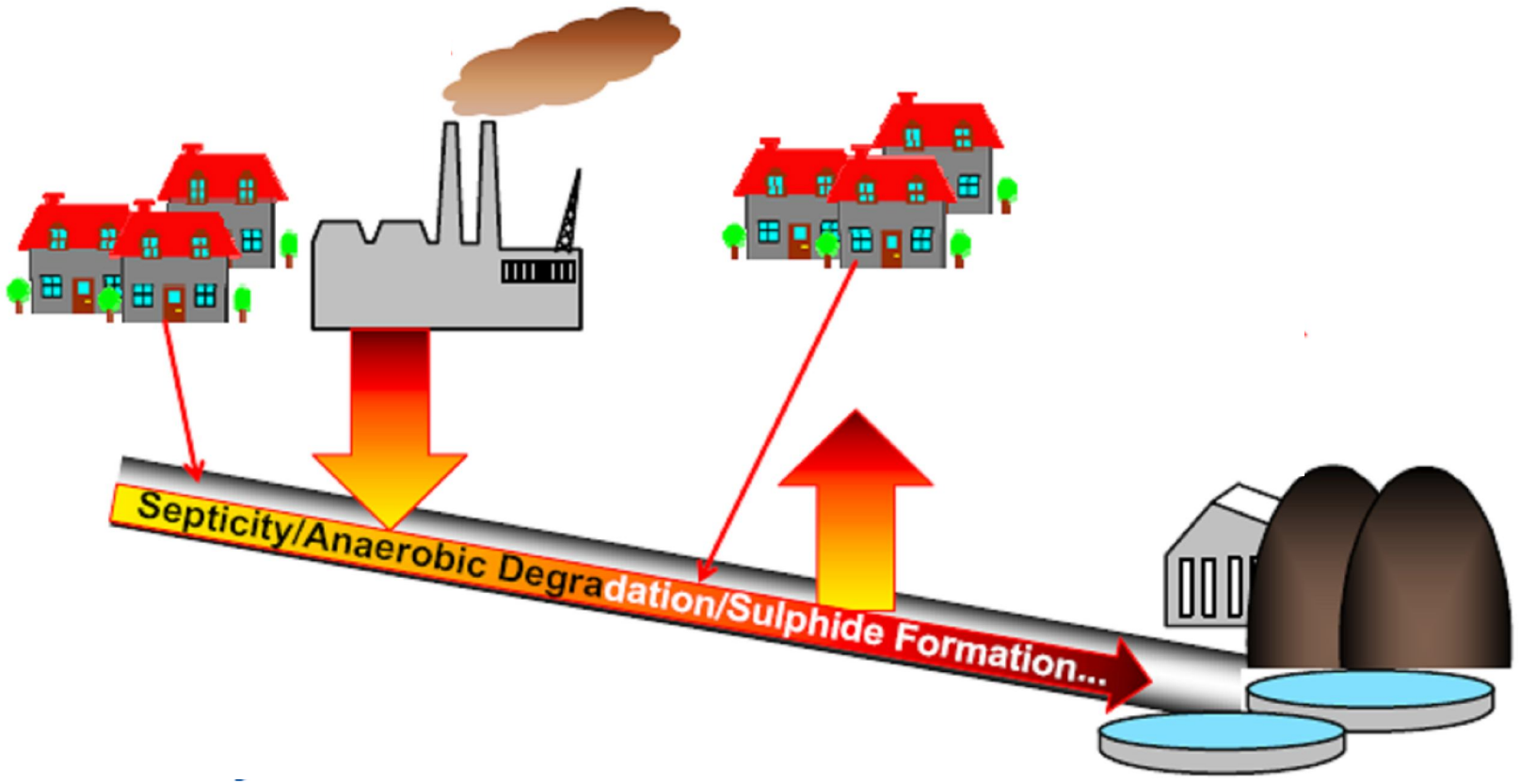
Hypochlorite

Ozone

Odour Formation in Sewers

- Sewers: Collection and Transport of domestic or industrial wastewater to WWTPs.
- Sewer Networks are Bioreactors where a high number of Chemical and Biochemical reactions ocurr.
- Odour Formation $f\left(\text{RE} - \text{DOX Conditions in the Network}\right)$
  - **Aerobic Conditions:** ☺-Low Risk of odour formation, of unhealthy conditions and of corrosion problems. ☻-The consumption of easily biodegradable organic matter limits the efficiency of denitrification and Biological P removal processes.
  - **Anaerobic Conditions**: ☻- Intense Odour Formation, Health and Corrosion Risks. Problems associated with the formation of H_2S

Odour Formation in Sewers



The Development of Anaerobic Conditions in Sewers is the main factor responsible for Odour Formation

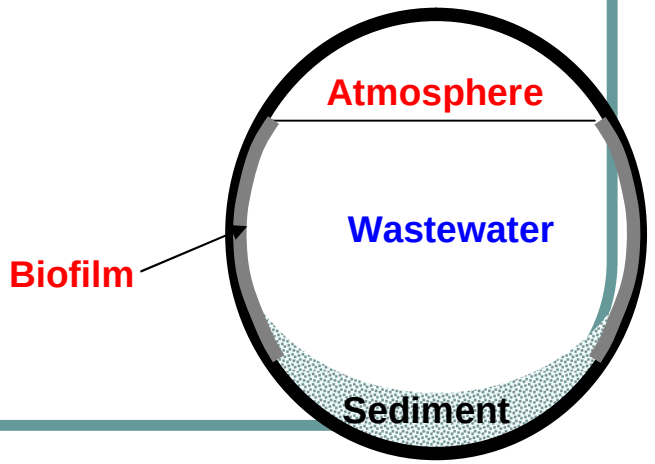
Odour Formation in Sewers

H_2S-mediated Odour Corrosion Problems

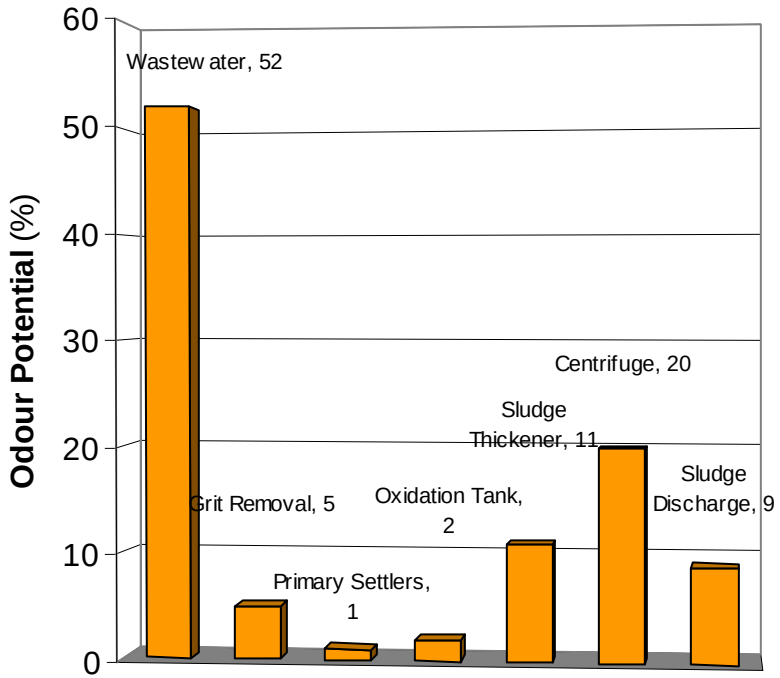
[H_2S] up to 300 ppm
LETHAL

The generation of malodours from WW in sewer networks occurs as a result of the interactions between:

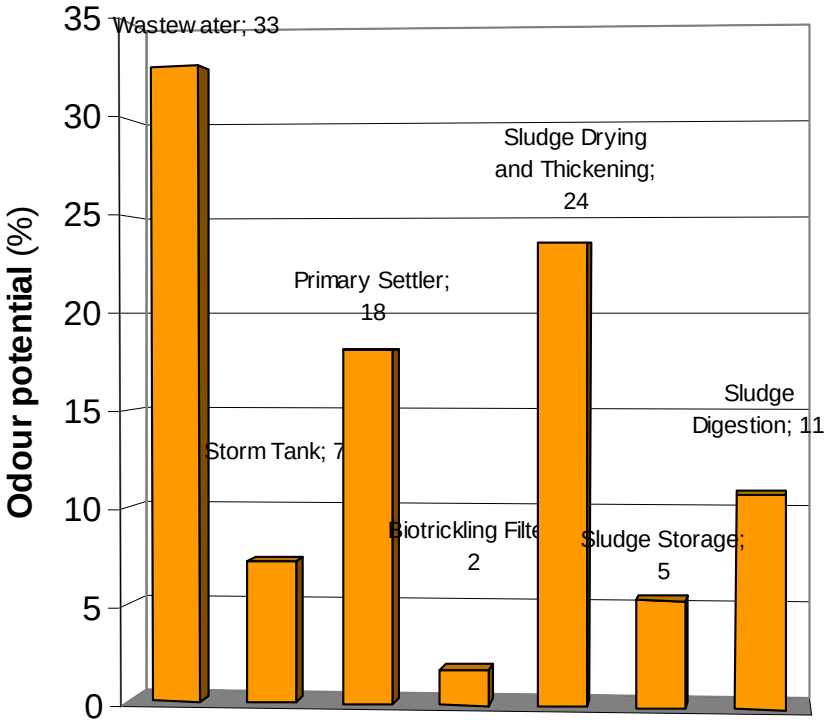
- Wastewater
- Biofilm attached to the sewer walls
- Sediments at the bottom of the pipelines
- Sewer Atmosphere.



Odour Sources in WWTPs



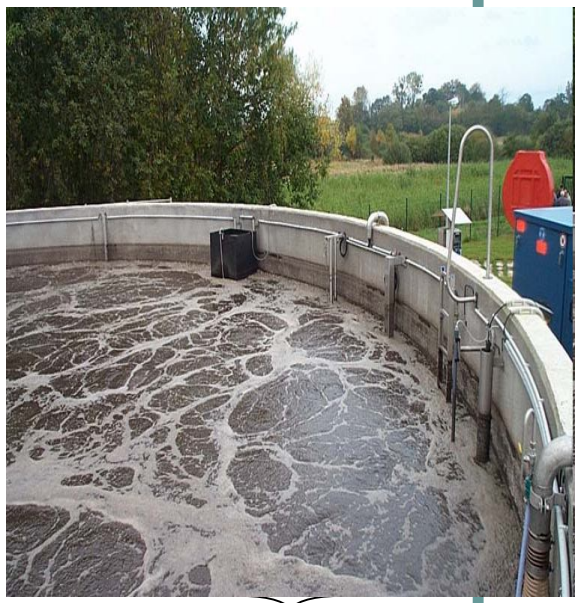
(Zarra et al. 2007)

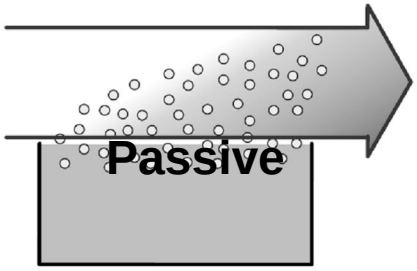


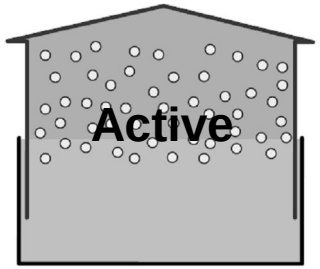
(Vincent et al. 2001)

Odour Sources in WWTPs

Primary Treatment **Sludge Thickener** **Activated Sludge**







Odour Sources in WWTPs

Type of Odour Sources

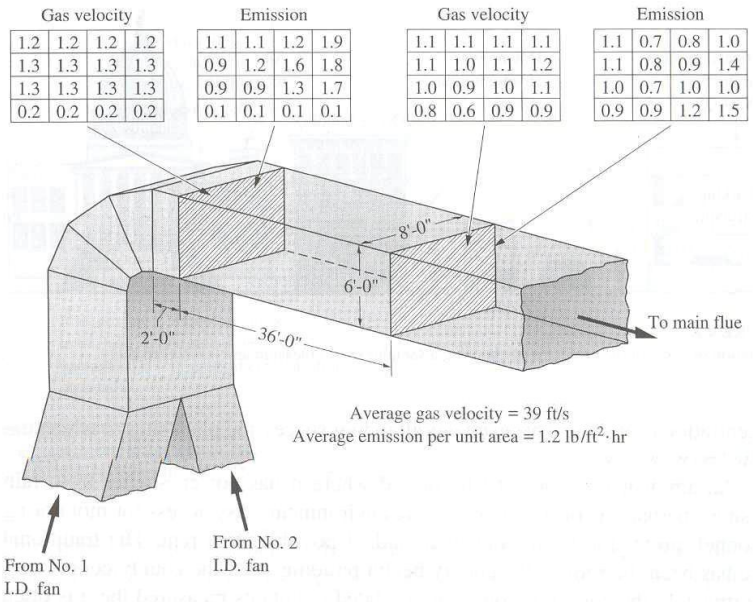
- Punctual: Locally restricted emissions e.g, Chimney, Bioscrubber
- Linear: Elongated sources such as receiving wastewater channels
- Superficial: Extensive emission areas such as primary settlers
- Mobile: Sources changing position. Vehicles transporting odorous residues.

Characterization of odorous emissions

- Odour Characteristics
  - Concentration
  - Type of odour
  - Intensity
  - Hedonic Tone
  - Annoyance potential
- Emission Flowrates
- Identification and Quantification of Odorants within the complex mixture (GC-MS. GC-FID, Jerome, etc.

Odour Emission Characterization

Active Punctual Sources (Chimney)



The main problem in active sources is representative sampling

Active Superficial Sources (e.g. Biofilters)

Differential Sampling in which the sampled area must be 1 % of the Total Surface)

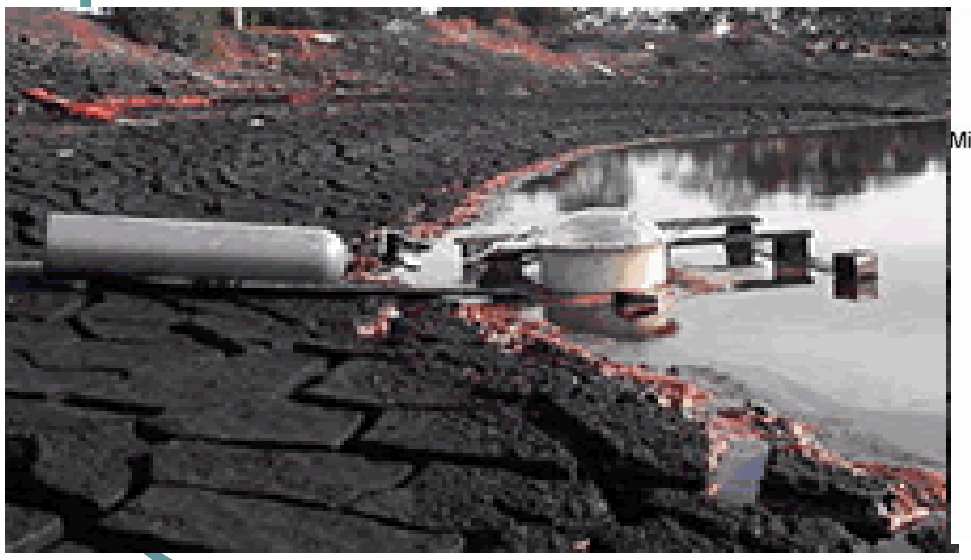
$$c_{average} = \frac{\sum VAc}{\sum VA} = \left[\frac{\sum Vc}{V}\right]_{\text{equal sections}}$$

Sampling Techniques

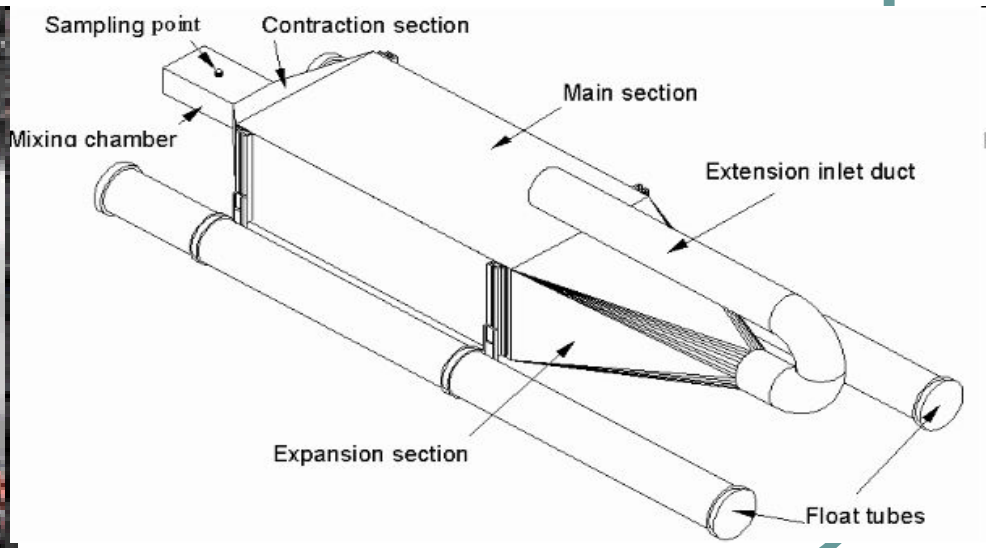
Superficial Source Sampling

- Superficial sources without external air flow, such as primary sedimentation tanks and sludge storage, require special sampling devices
- Two types of sampling devices:

Static Hoods



Wind Tunnels



The surface is swept with odour-free air: 5-24 l/min (Hoods); 1800 l/min (Wind tunnels)

Sampling Techniques

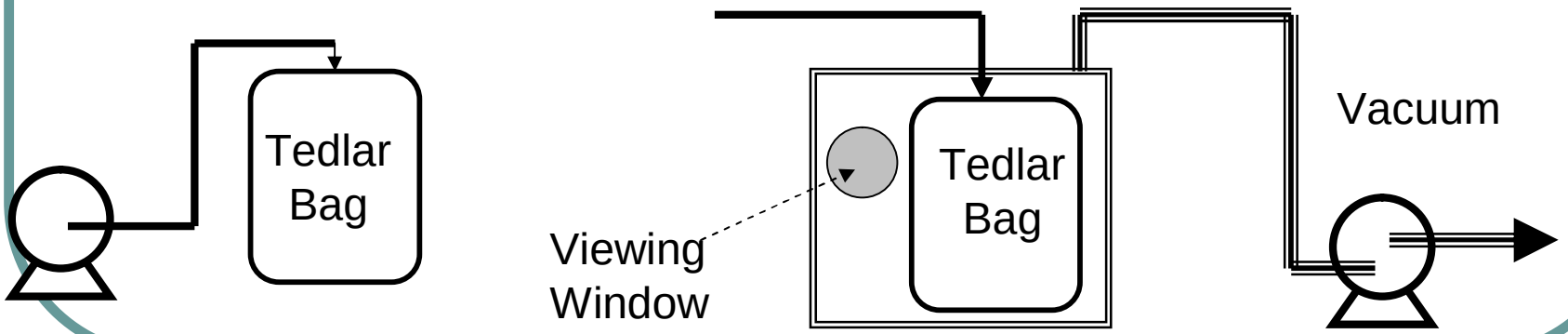
- Collection in Tedlar Bags
- Bags filled using both direct and indirect methods

Direct Method

- Sample is pumped
- Contamination risk
- Not very common

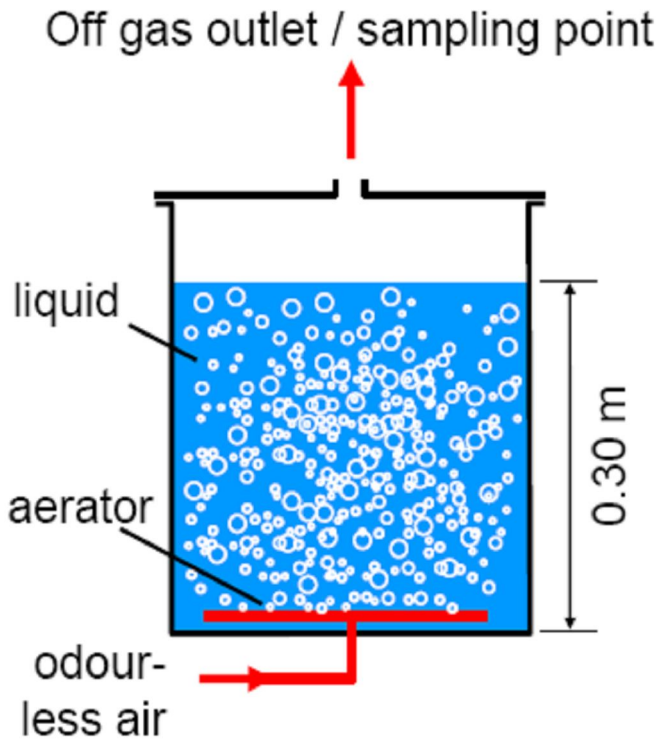
Indirect Method

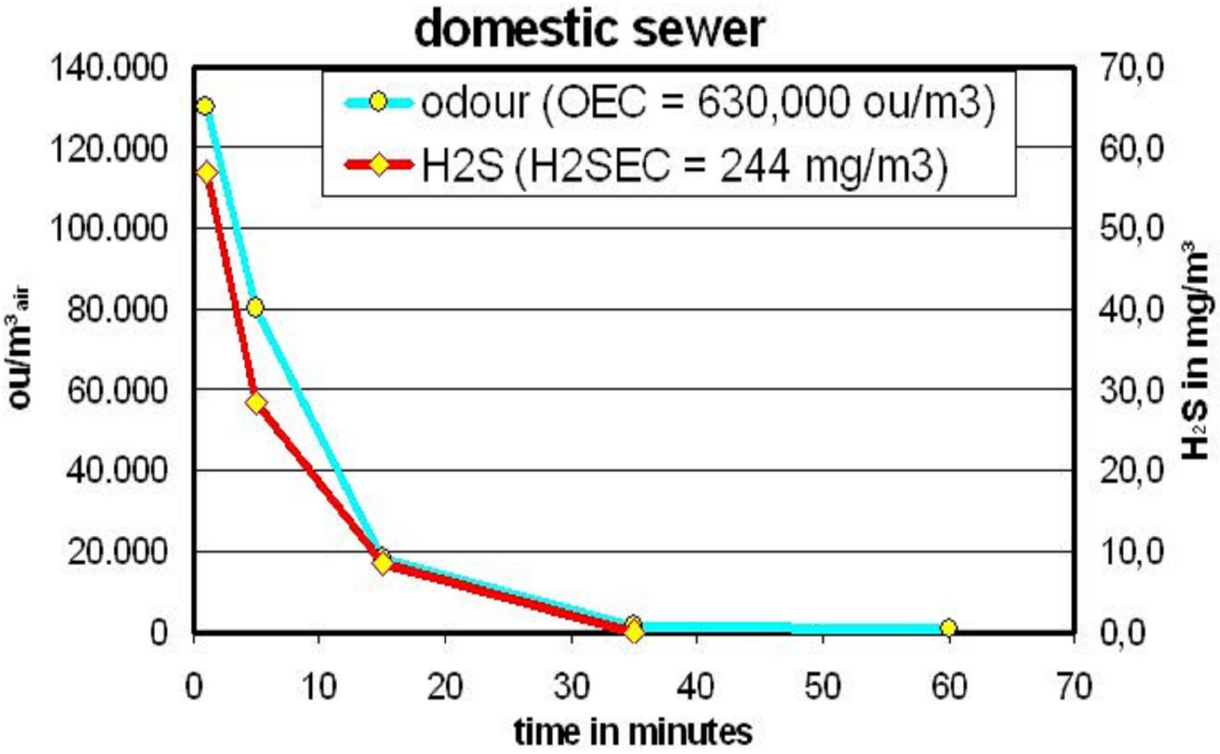
- Bag in a gas-tight vessel + vacuum system
- Low risk of contamination
- Very common



Odour Sources in WWTPs

ODOUR EMISSION CAPACITY (OEC): The total mass of odorous compounds, expressed in OU m^{-3}_{liquid}, that can be removed from 1 m^3 of liquid in standard conditions. Odour concentration measurement is carried out by olfactometry (Frechen and Köster, Wat.Sci.Tech.,1998)

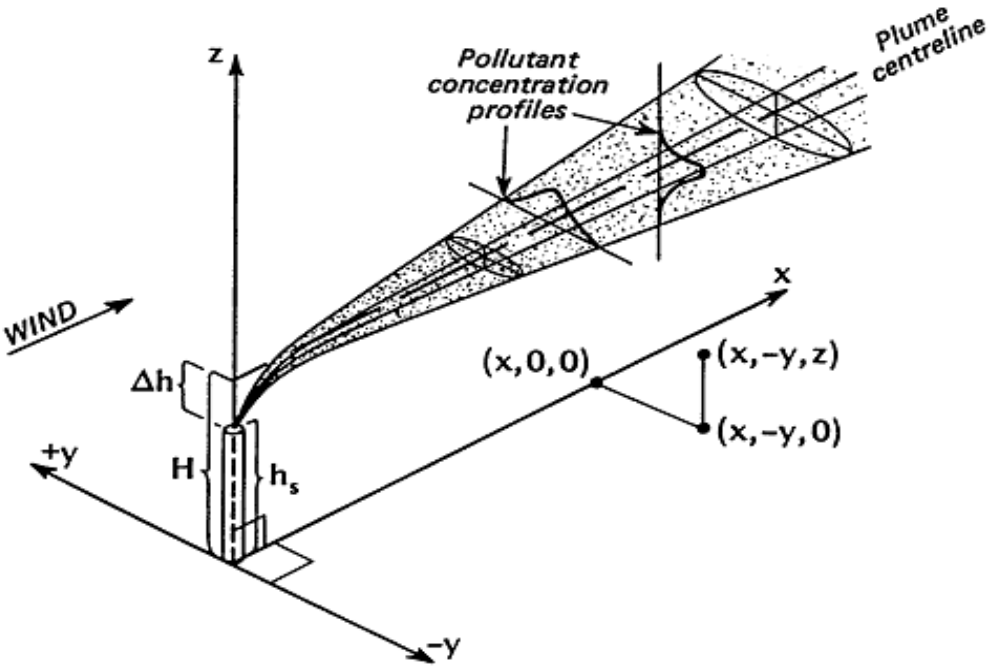


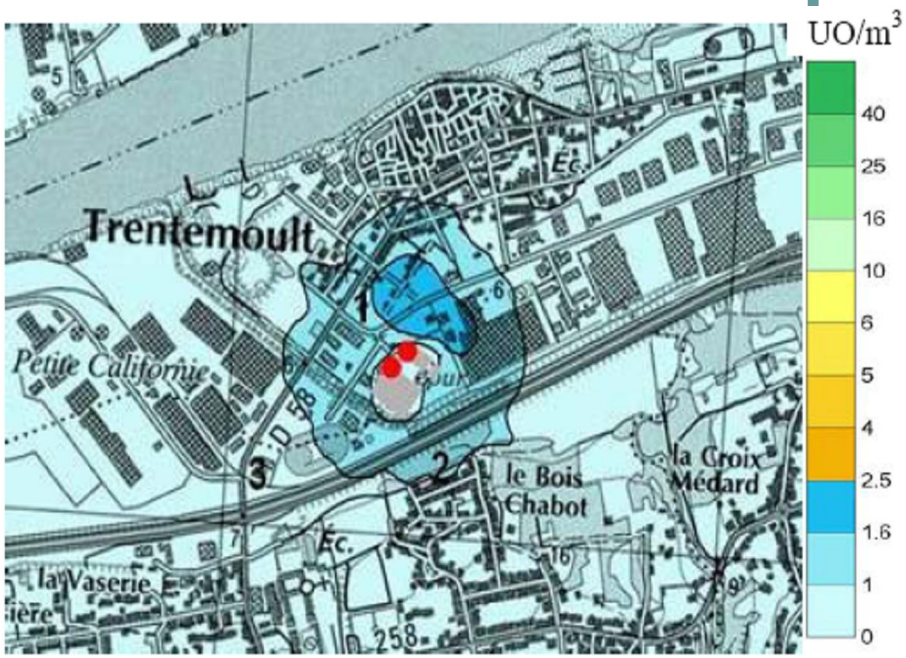


From Odour emissions to Odour Impact

An accurate characterization of odour emission rates in OU_E/s is needed

$$C_{(x,y,z)} = \frac{E}{2\pi\sigma_y\sigma_z u}\exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]\left\{\exp\left[-\frac{1}{2}\left(\frac{z-H}{\sigma_z}\right)^2\right]+\exp\left[-\frac{1}{2}\left(\frac{z+H}{\sigma_z}\right)^2\right]\right\}$$





From Odour emissions to Odour Impact

Limitations of Odour Dispersion modelling

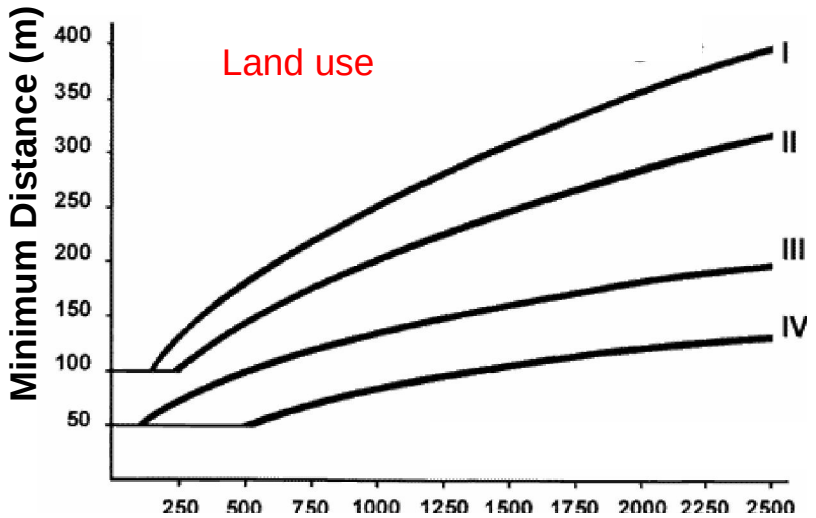
- High Uncertainty due to the variations in atmospheric conditions. Models are run with hourly-averaged meteorological data.
- High Uncertainty in the determination of odour emission rates: Emission rates depend on the amount and composition of the residual wastewater and atmospheric conditions.
- The models can not be applied to all prevailing meteorological conditions. Most of the models can only be applied at wind velocities > 1 m/s (at velocities < 1 m/s odour concentrations are higher)
- Limited meteorological information: There might be significant differences between the conditions prevailing at the WWTPs and those measured in the nearest Meteorological Station.

Legislation: Standards

Types of Standard:

1- Simple and Old:

- Minimum Distance Standard: They establish minimum distances from the point of emission based on previous practical experience, on the plant size and category.



(Bongers, 2008)

Legislation: Standards

- **Maximum Emission Standard**: They establish emission limits depending on the type of activity, based on the previous knowledge of impact degree and emission magnitude.

E. g. If the flow rate emitted is higher than 80 m^3/min the maximum allowed concentration is 80000/Q (ou_E m^{-3})

2- New & Sophisticate: They integrate the degree of annoyance:

- **Standard of Maximum Impact**: They limit the degree of impact in the neighboring residential areas or at the facility boundary. The emission is therefore indirectly limited. It is the most common nowadays

- **Standard of Maximum annoyance**: They are established based on surveys. They determine the degree of satisfaction during episodes of odour contamination

.. what about European Legislation??

Regulation and Policies in Europe

Country	Limit (OU m^{-3})	% hour / year	Category of land usage	Observations
Germany	1	3	Residential	
	1	5	Residential and restructured	
	1	8	Business and housing development with mixed use	
	3	3		
	1	10	Housing developments with farming activities	
	3	5		
	1	10	Urban/industrial area	
	3	3		
Denmark	5-10	0.1		Facility interior
	0.6-20	1		Facility Boundary
	1	2	Residential	Existing facilities
	1	0.5	Residential	New facilities
Holland	1	5	End town and shopping centre residential area	
	0.5	2		Very unpleasant odour
	3.5	2		Other odours

.. and… what about Spain?

The Law 34/2007, November 15th, regarding air quality and atmosphere protection applies to

- **091001- Industrial Waste Water Treatment**
- **091002- Domestic and Commercial Wastewater Treatment**
- **091003- Sludge Treatment**
- **091005- Compost Production**
- **091005- Biogas Production**

This Law establishes fines from 200.001 to 2.000.000 euros and the definitive closure of the facility

However Neither emission nor impact limits are established!!!!!!

.. so.. What´s up??

Based on the Law 3/1998 and the regulation 136/1999, the council administration of the odour legislation was reinforced.

Draft law — **Cataluña**

Municipal By-Law — **Bañolas (Girona)**

Municipal By-Law — **Sant Vicent De Raspeig (Alicante)**

Municipal By-Law — **Llica de Vall**

- Emission limits
- Impact limits

3 OU_E/m^3 at 98 %

5 OU_E/m^3 at 90 %

(in residential areas)

How can we minimize these emissions??

Emission Control

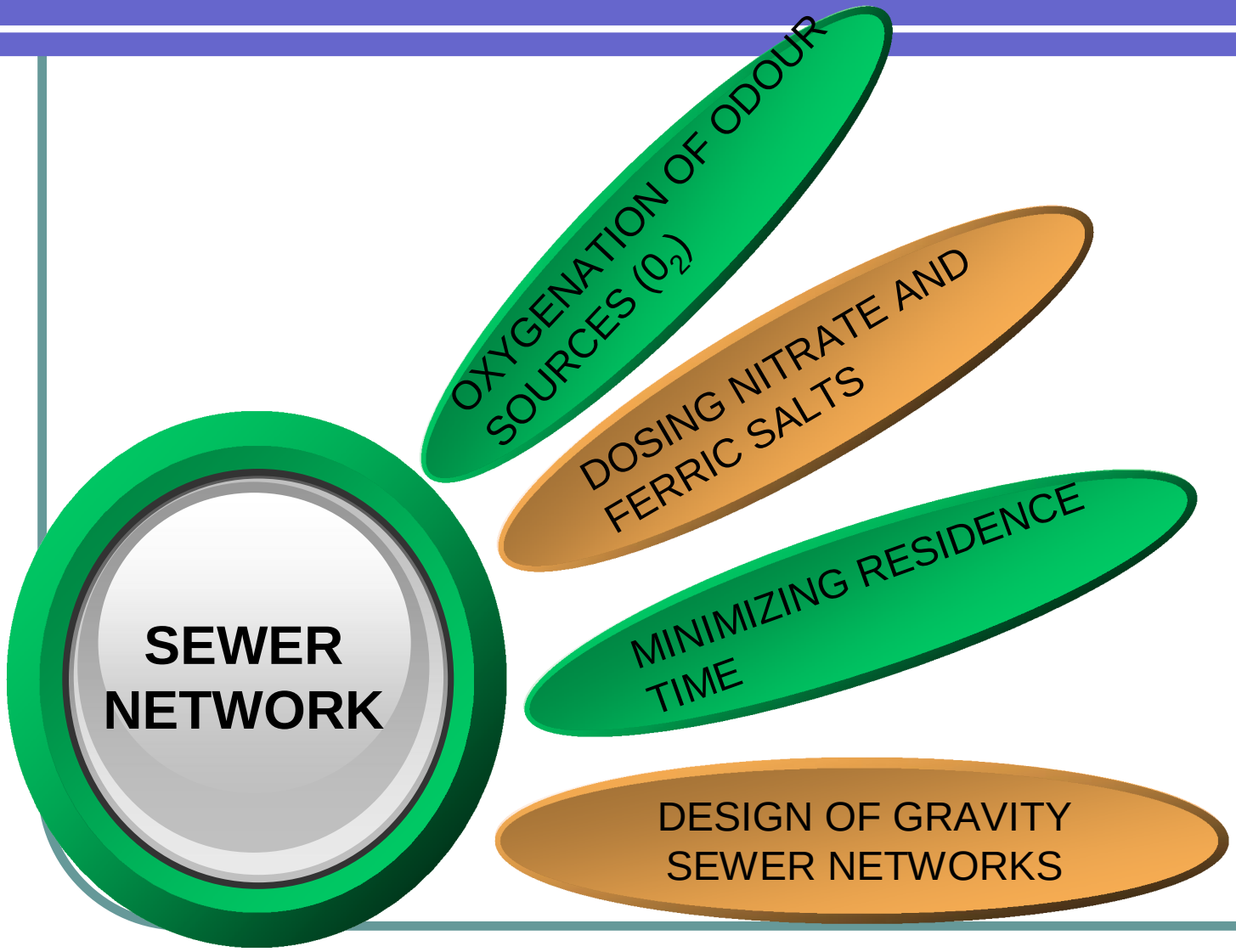
Emission and Formation Prevention

- SEPTICITY PREVENTION IN SEWER NETWORKS
- PREVENTION IN WWTPS
- CONTAINMENT

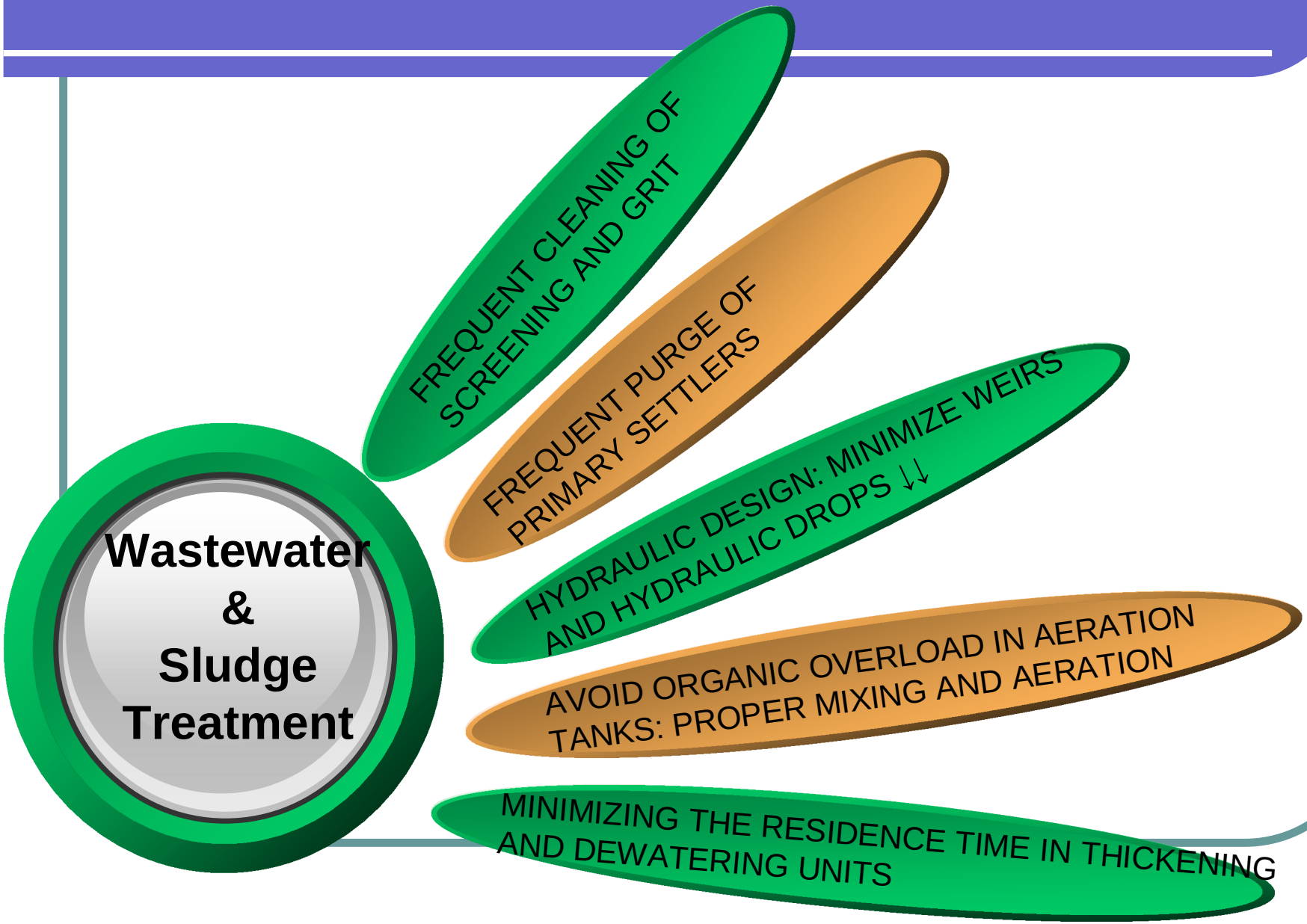
***End of the pipe* Treatments**

- SUPERFICIAL TREATMENTS
- PHYSICAL/CHEMICAL SYSTEMS
- BIOLOGICAL SYSTEMS

ODOUR REDUCTION AT THE ORIGIN → PREVENTION

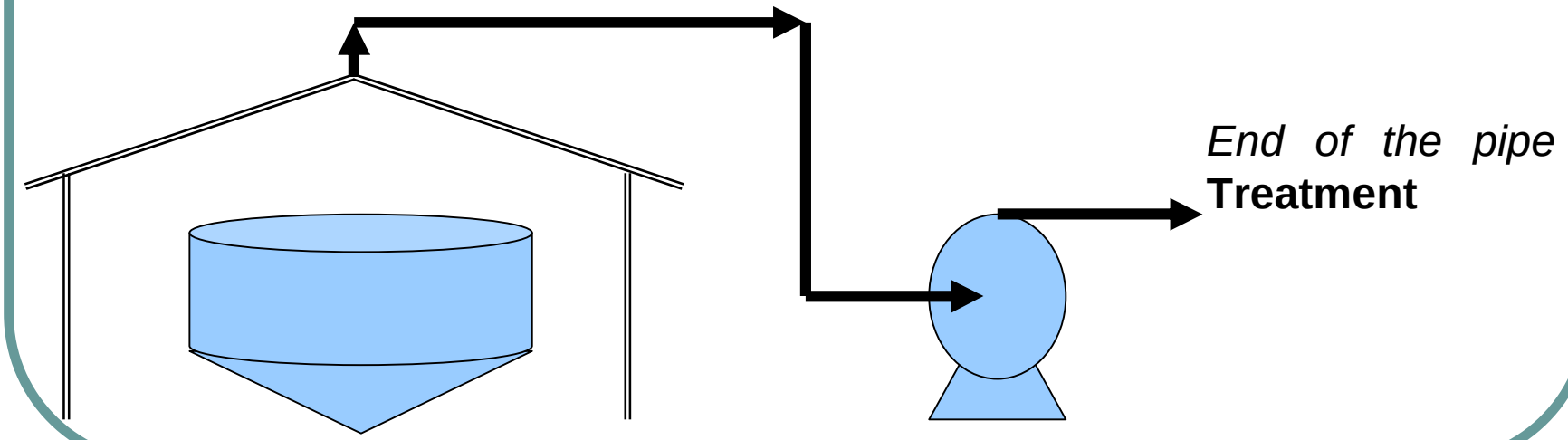


ODOUR REDUCTION AT ORIGIN → PREVENTION



Odour Containment

- Odour containment in WWTPs is carried out by covering the key odorous process
- Odorants are then pumped into the a treatment reactor



PROCESS COVERING: CONTAINMENT

1- **Low-level Covers** are placed just above the liquid level

Minimum headspace between the liquid and the cover

Suitable when the volume of odorous air must be minimized

High concentration of odorants in these emissions

Disadvantages:

- Visual inspection of the process unit is difficult (bulking in aeration tanks)
- Sampling is also hindered

Odour Containment

Materials:

- Wood
- Concrete
- Aluminum
- Reinforced Fiber Glass (with UV protection additives)

Odour Containment

High-level Covers: there is sufficient headspace to allow entry for personnel and maintenance work

Cover spans out from fixed walls built independently of the existing tank.

Travelling bridges and machinery at the settling tank are accommodated within the tank structure

Access for maintenance is provided via doors at the side wall of the covered tank

Designed with a slight negative pressure to prevent fugitive emissions

End of the pipe Treatment

SUPERFICIAL TREATMENT

- MASKING, INHIBITING, OR NEUTRALIZING AGENTS
- SUITABLE FOR DIFFUSED SOURCES OR VERY VARIABLE FLOWRATES
- ONLY MASKING AGENTS ARE EFFICIENT

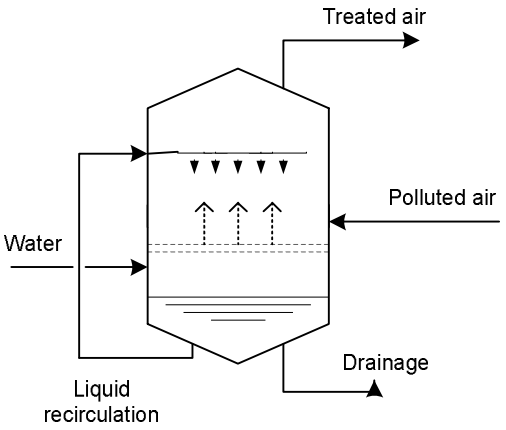
End of the pipe Treatment

CHEMICAL SCRUBBERS

CONVENTIONAL TECHNOLOGY
CHEMICAL OXIDATION OF ODOURS

HIGH COST OF CHEMICAL REAGENTS
NaClO 8-10; $KMnO_4$ 6-7; H_2O_2 1-4 g/gH_2S

HIGH EFFICIENCIES AT SHORT RT (1-10 s) :
H_2S 98 % Y 90 % MERCAPTANS



Investment 12-55 € /(m^3h^{-1})

Operation 20-94 € /(m^3h^{-1})

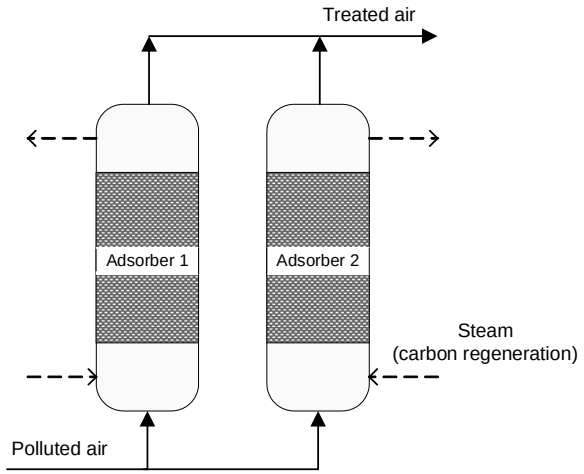
End of the pipe Treatment

ADSORTION

CONVENTIONAL TECHNOLOGY
ADSORTION + RETENTION

HIGH COST OF THE ACTIVATED CARBON
1- 4 €/Kg
POOR PERFORMANCE AT HIGH MOISTURE CONTENTS

HIGH EFFICIENCIES AT SHORT RT
HYDROPHOBIC VOCs 90 - 99%



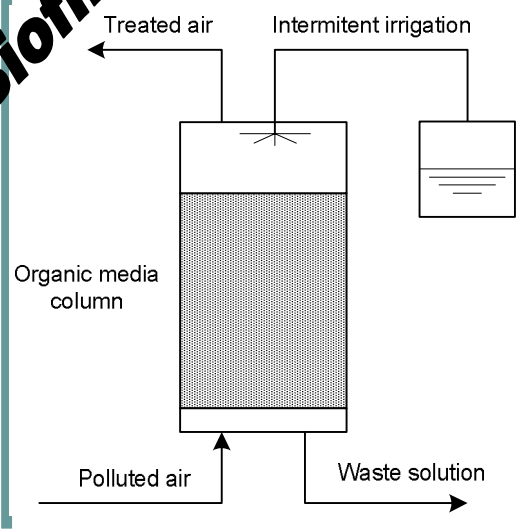
Investment 8-94 € /(m^3h^{-1})

Operation 8-27 € /(m^3h^{-1})

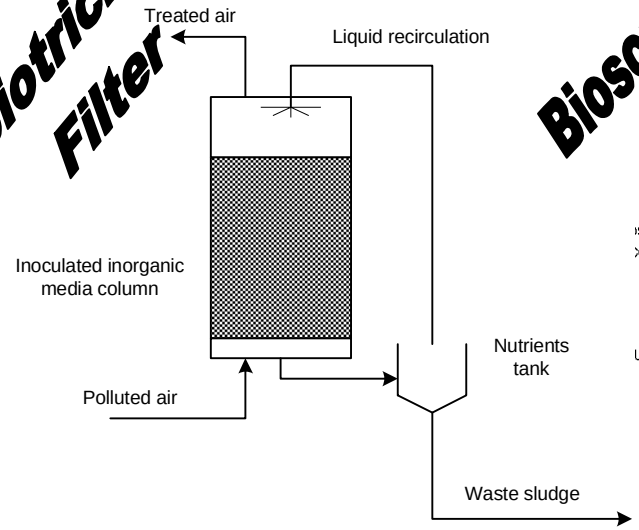
End of the pipe Treatment

BIOLOGICAL TREATMENT

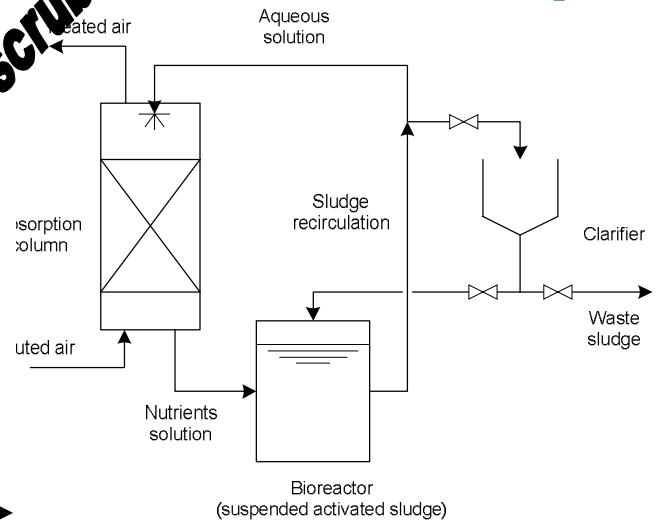
Biofilter



Biotrickling Filter



Bioscrubber



HIGH EFFICIENCY AT 20s - 2 min
H_2S AND VOC- RE OF 90-100 %

Inv 5-68 € /(m^3h^{-1})
Op 2-8 € /(m^3h^{-1})

HIGH EFFICIENCY AT RT 1-10 s
H_2S 90-100 % VOCS < 40 %

Inv 5-20 € /(m^3h^{-1})
Op 2-8 € /(m^3h^{-1})

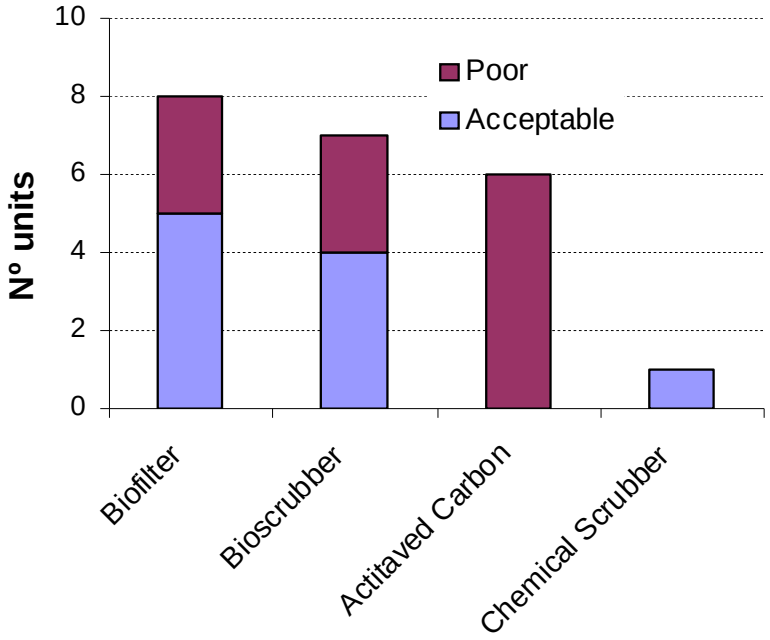
HIGH EFFICIENCIES
80-95 %

Inv 23-92 € /(m^3h^{-1})
Op 2-8 € /(m^3h^{-1})

…..And what do the recent studies report?

Severn Trent Water Ltd (UK).
22 Facilities

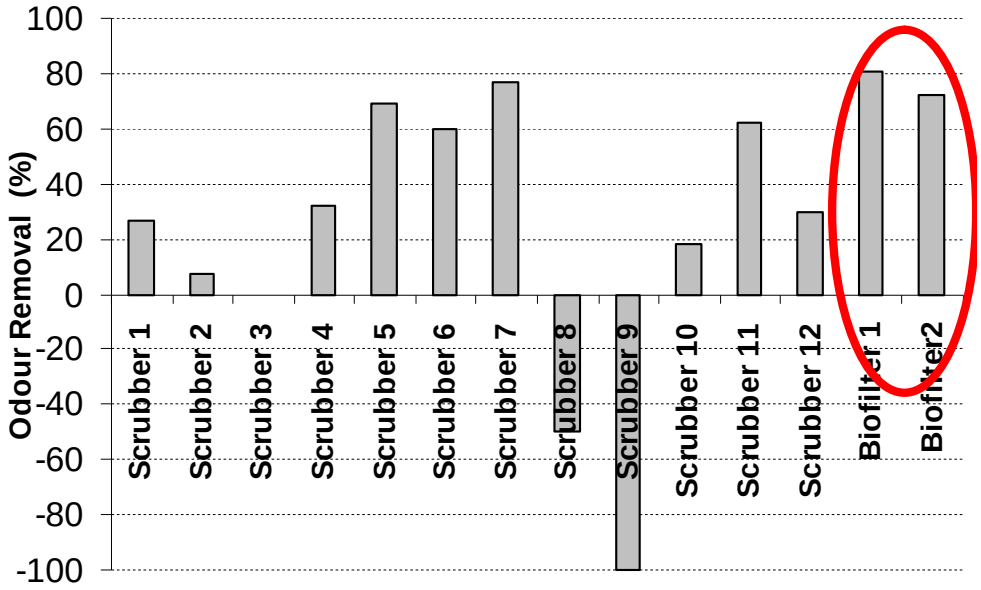
(Jeavons et al. 2000)



14 Facilities (Brasil)

- 12 Chemical Scrubbers
- 2 Biofilter

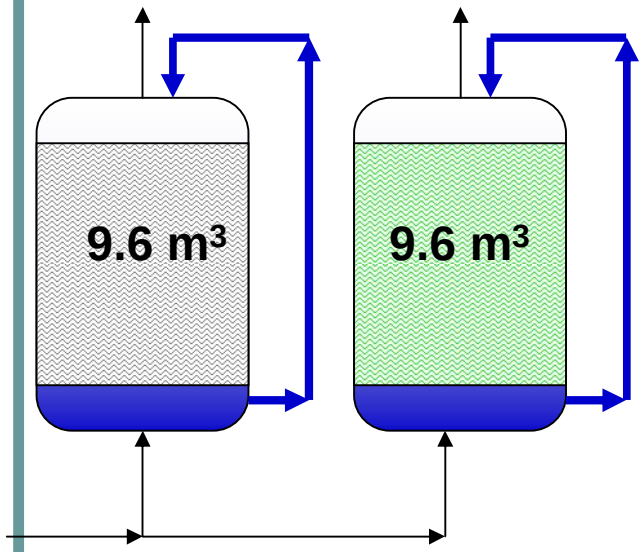
(Quadros et al.. 2008)



From a Chemical Scrubber to a Biotrickling Filter

¿¿Is it Profitable??

WWTPs: *Fountain Valley* (California); **Orange County Sanitation District (2004)**



Odours air from Plant Headworks

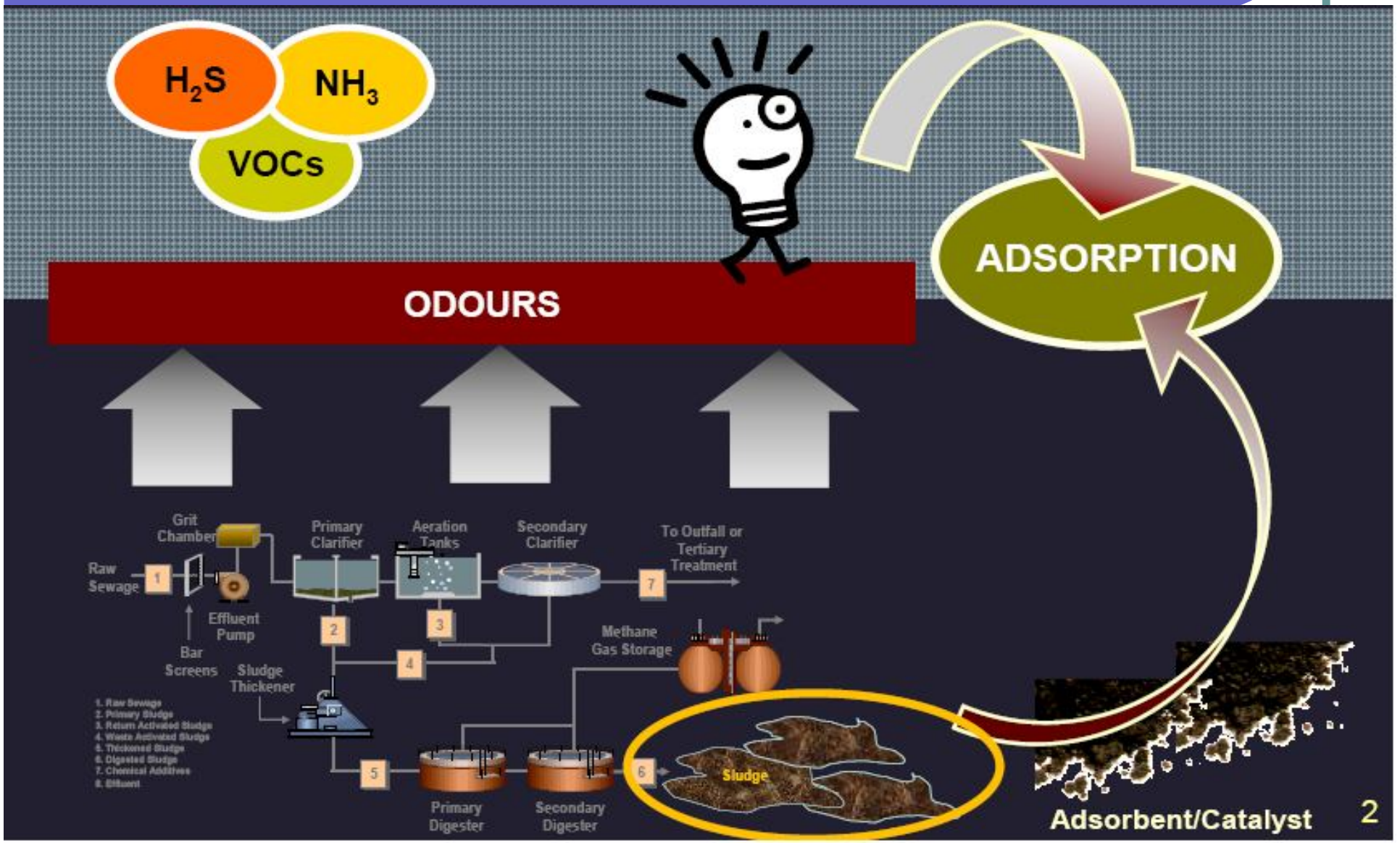
379200 m^3 air d^{-1}

	Chemical Scrubber	Biotrickling Filter
EBRT (s)	2.2	2.2
H_2S Removed (kg/año)	1040	1370
Energy (€/year)	16300	14200
Reagent (€/year)	9143	0

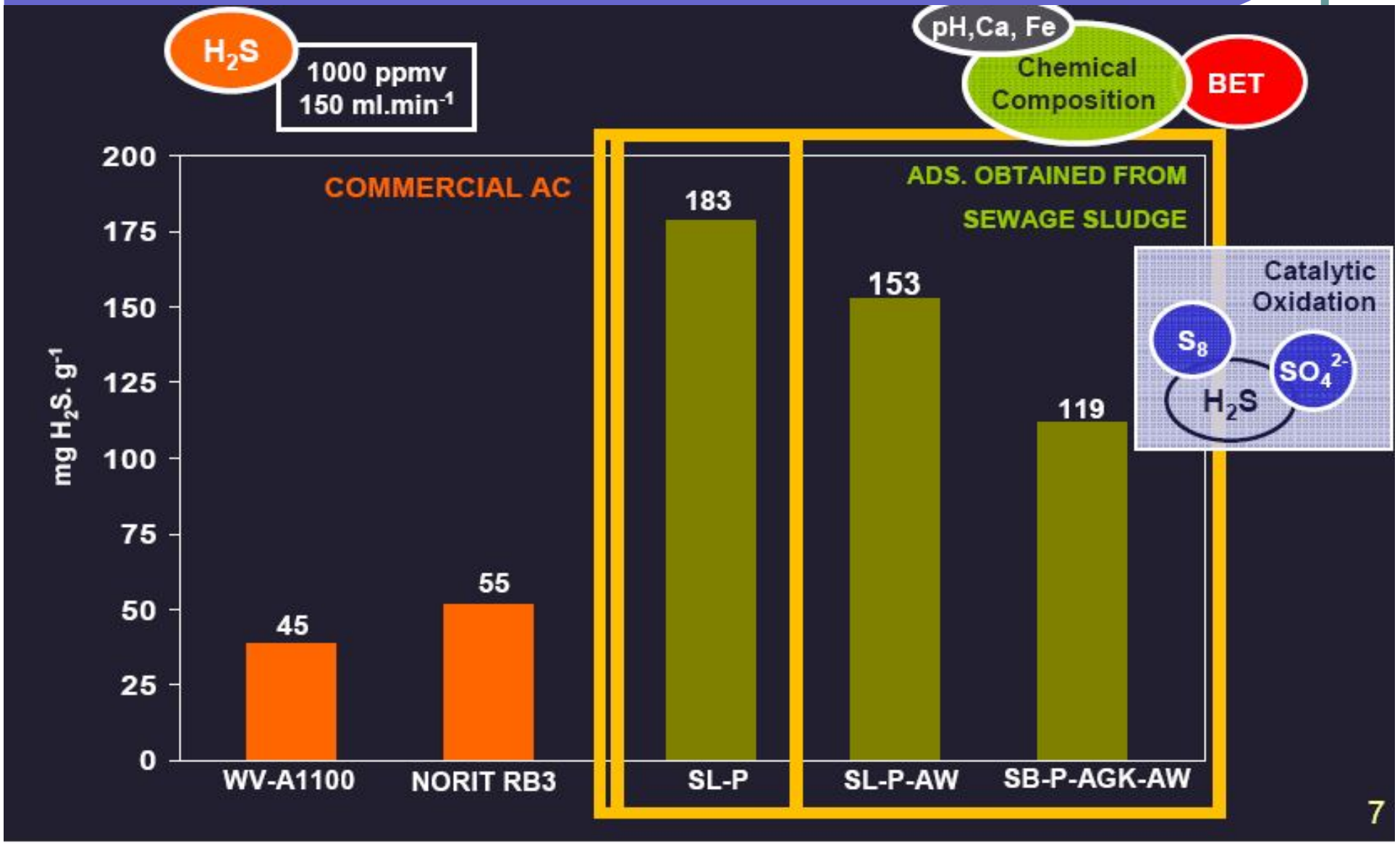
Reconversion Cost 15300 €

Amortization 1.3 Years !!!!!

EMERGING TECHNOLOGY



CATALYTIC CARBON

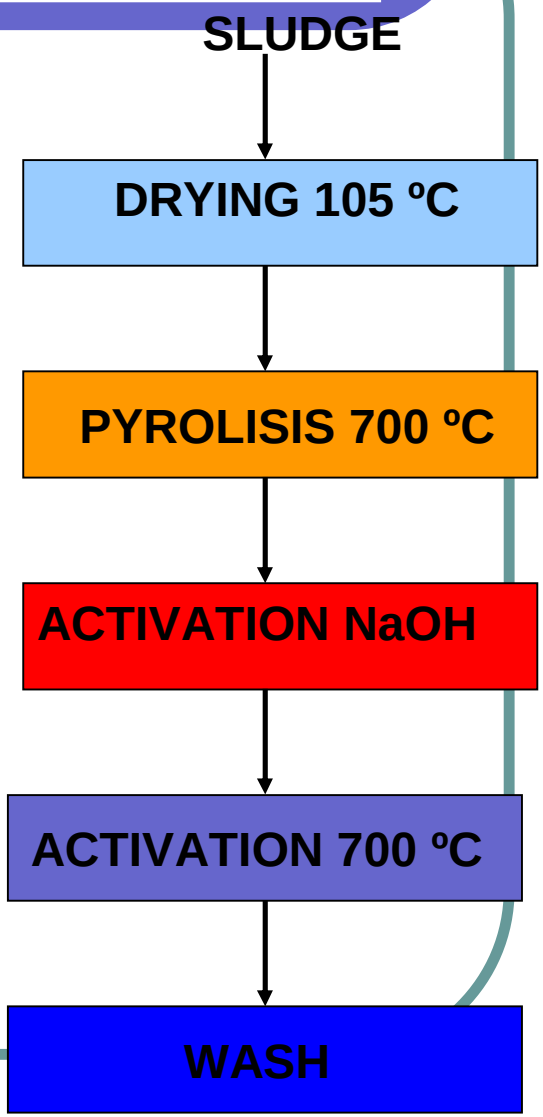


EMERGING TECHNOLOGIES
CATALYTIC CARBON

ADSORTION & REACTION WITHIN THE ACTIVATED CARBON MADE OF SLUDGE

COSTS SIMILAR TO ACTIVATED CARBON
2-3 € / KG

REMOVAL RATES UP TO 10 TIMES HIGHER THAN CONVENTIONAL ACTIVATED C
NEED FOR: PROCESS OPTIMIZATION



EMERGING TECHNOLOGIES
ODOUR DIFFUSION IN ACTIVATED SLUDGE

Odour Removal Efficiencies
99.7% < H_2S & odour < 99.9 %

REUSE OF MALODOURS AIR AS O_2 SOURCE IN AERATION

VERY COST-EFFICIENT TECHNOLOGY IF THE PLANT ALREADY HAS AERATION BY DIFFUSION

ADVANTAGEOUS WHEN LAND IS SCARCE