N_2O PRODUCTION AND EMISSIONS IN WWTP

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WHY MEASURE N_2O?

- Global warming induced by anthropogenic increases of GHGs
  - ↑CO_2 40%
  - ↑CH_4 150%
  - ↑N_2O 20%

  since 1750s

- N_2O
  - GWP 298 x CO_2
  - 3.1 $GtCO_2eq$ in 2010
  - 3.5% origniates from WWT

WHY MEASURE N_2O?

- First full-scale measurements in 1990s
  - 3.2 $gN_2O\text{-}N\ p^{-1}y^{-1}$ or
  - 0.035% of TKNin

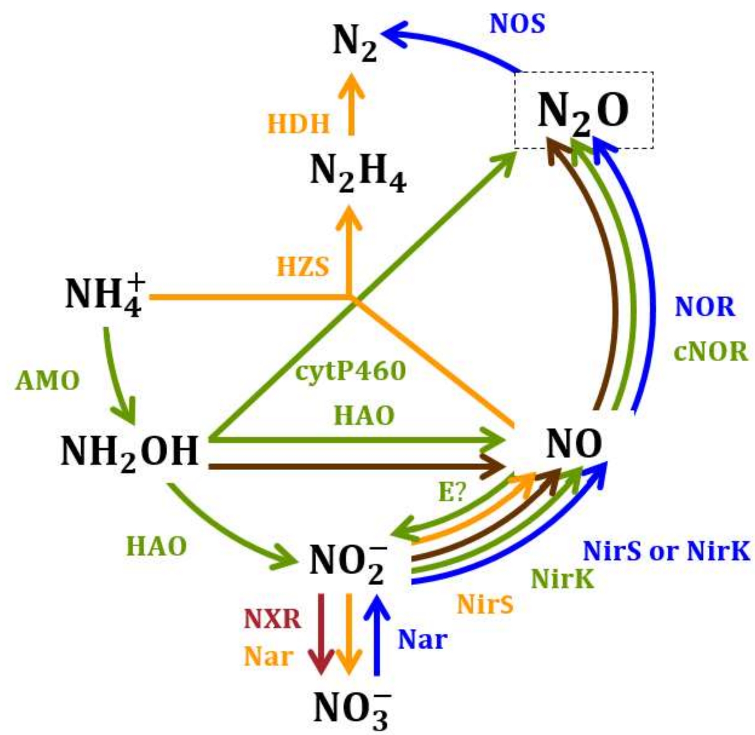
  Czepiel et al., 1995
  - IPPC 2006 calculation factor

- Recent research:
  - N_2O 0.001 -25% of influent N-load
  - 1% ↑N_2O --> 30% ↑C-footprint

HOW IS N_2O PRODUCED IN WWT?

- AOB
- HDN
- Chemical reactions

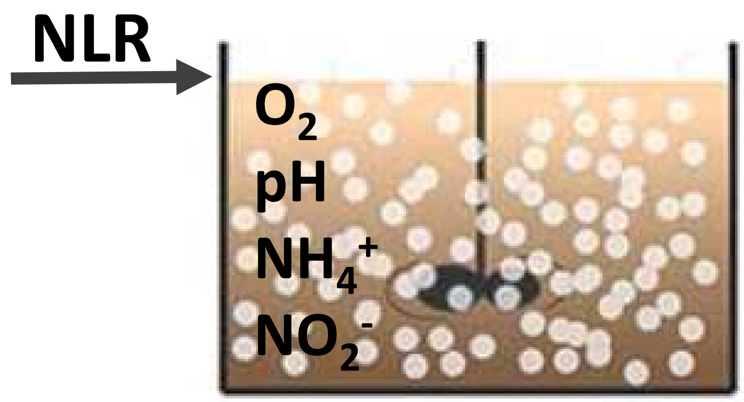
- Anammox
- NOB



PROCESS CONDITIONS PRODUCING N_2O

<u>Nitrification:</u>

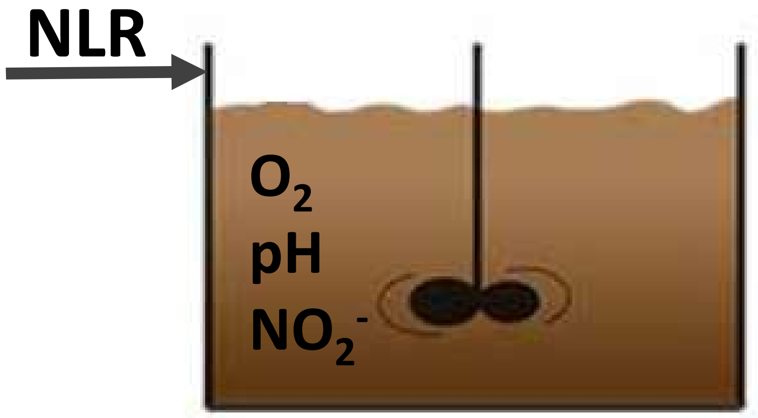
- Low DO
- High NO_2^-
- Sudden shifts of
    - pH,DO, NH4+
- Transient aerobic conditions
- NH_4^+ overload
- High NH_4^+ oxidation rates
- Incomplete nitrification



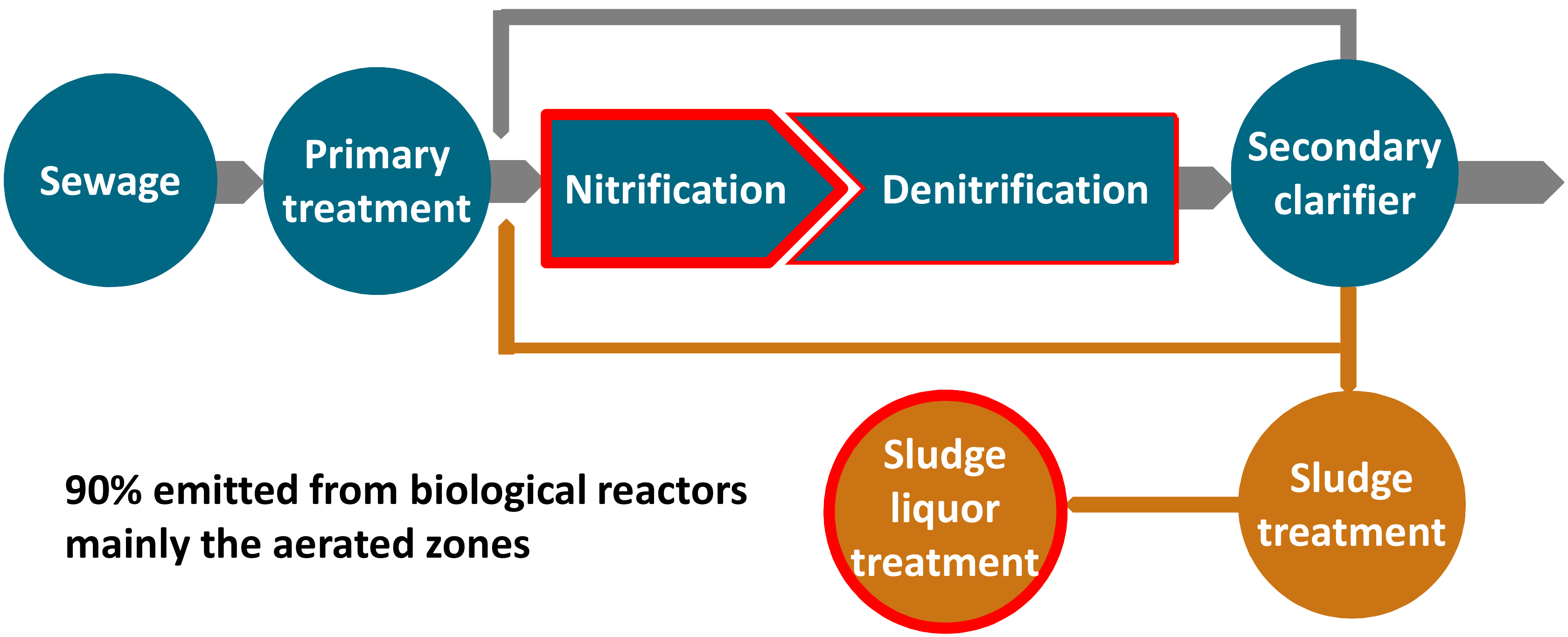
PROCESS CONDITIONS PRODUCING N_2O

<u>Denitrification:</u>

- Presence of O_2
- Low pH
- Low COD/N ratio
- Type of COD source
- High NO_2^-
- Low temperature reduces NO and N_2O reductase activities



WHERE IS N_2O EMITTED?



90% emitted from biological reactors mainly the aerated zones

LIQUID-GAS MASS TRANSFER

N_2O emission rates governed by the mass transfer coefficient:

$$k_L a_{N_2O} = \frac{\frac{Q_{air} \cdot p_{N_2O}}{R \cdot T} \cdot MW_{N_2O}}{V_R \cdot \left(C_{N_2O} - C_{N_2O}{}^{*}\right)} \; h^{-1}$$

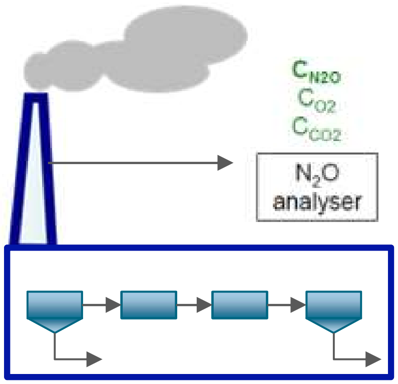
Main external factors influencing N_2O emissions:

1) temp of liquid phase
2) liquid phase N_2O concentration
3) aeration and stirrer effect

MEASUREMENT TECHNIQUES

Gaseous phase

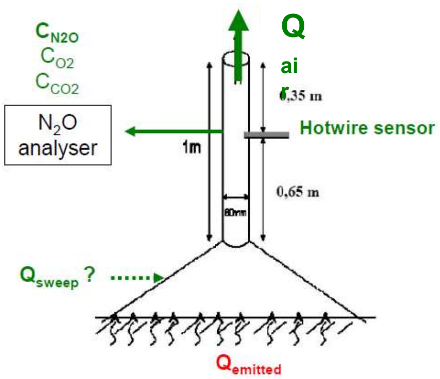
Total exhaust



Pros:
Entire emissions
Online for long periods

Cons:
Not process specific
No info on hot spots

Point source



Pros:
Process specific
Online for long periods

Cons:
Covers small area

MEASUREMENT TECHNIQUES

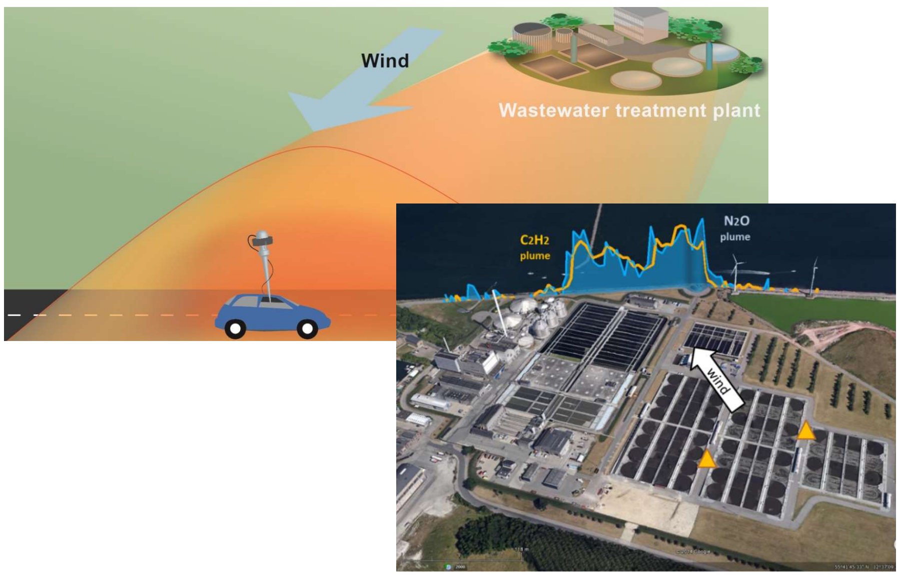
Liquid phase

Pros:
Insitu dynamics
Online for long periods
Cons:
k_La dependent
Fragile
Temperature dependent
Short life time of sensor

MEASUREMENT TEHCNIQUES

Tracer gas dispersion

A. Delre et al. / Science of the Total Environment 605–606 (2017) 258–268



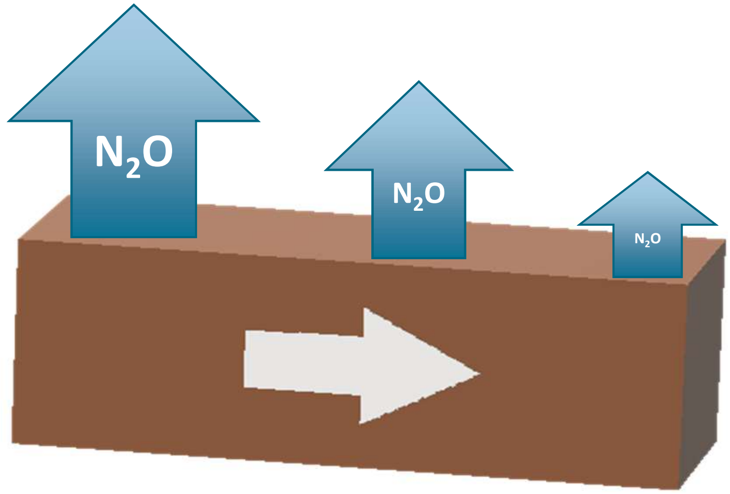
Pros:
Entire WWTP emissions
Possible to capture hot spots

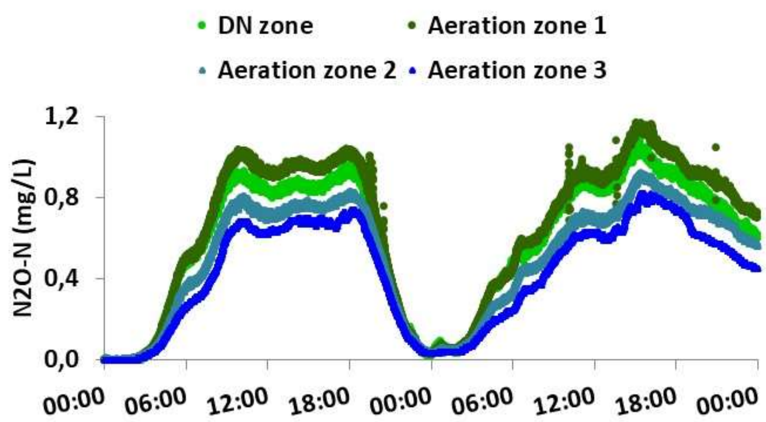
Cons:
Wind dependent
Sensitive to background noise
Short periods of measurement

SPATIAL VARIATIONS

- Occur due to gradients in:
    - DO, NH4+, NO2-, N-load, MLSS etc
    - Aeration regime

- Characterization to:
    - Correct quantification
    - Illuminate key drivers
    - Identify control measures

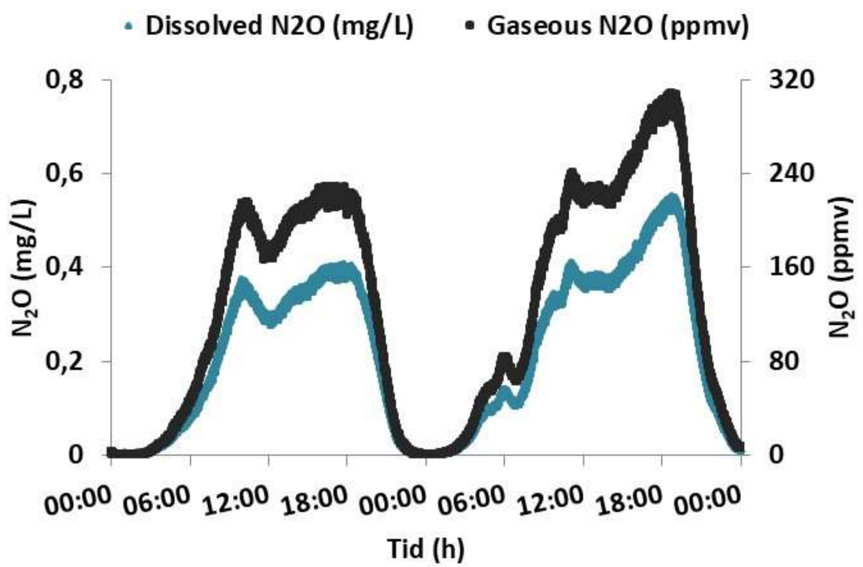




TEMPORAL VARIATIONS

DIURNAL

- Reoccurring diurnal pattern as an effect of:
    - influent load, DO, NH4+ oxidation rate, nitrite accumulation etc



SEASONAL

- Huge variations over a year
- Variation with temperature, MLSS, microbial community structure changes

N_2O EMISSIONS IN DIFFERENT CONFIGURATIONS

Main-stream systems

AAO	OD	Plug flow	SBR
• 0.1-3.4%	• 0.03-0.52%	• 0.04-1.9%	• 2.7-6.8%

Reject water systems

PN SBR	PN	PNA
• 3.8-19.3%	• 2.2-6.6%	• 0.4-2.0%

REPRESENTATIVE N_2O EMISSION FACTOR

WHY:

- Enables comparison between WWTP

HOW:

- Online high frequency
- Long term measurement
- Covering representative area/volume

} No standard method available

EXPRESSED AS:

- % of N load or
- % of N removed

IMPACT ON TOTAL CARBON FOOTPRINT

WWT system	N_2O % of N-load	% of C-footprint	Reference
SBR	6.8%	60%	Rodriguez-Caballero, 2015
Plug-flow	0.04%	13%	Aboobakar, 2013
Covered WWTP	2.8%	78%	Dealman, 2013
AS	0.5%	14%	Delre,2017 & 2019
BioDenipho	0.15-4.7%	48%	Yoshida, 2014 and Delre, 2019

- Mitigation of the N_2O emissions can reduce the total C-footprint of a WWTP significantly
- Not only energy use should be regarded

HOW TO MITIGATE N2O EMISSIONS?

- Continuous feeding
- High frequency aeration
- Long SRT
- Large reactor volume
- High MLSS
- Controll NH_4^+/NO_3^- concentrations
- Allow complete nitrification/denitrification
- Engineering the microbial community

THANK YOU FOR THE ATTENTION ☺

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