



Advancing N₂O Quantification towards Mitigation: Insights from France

13 MAY 2026

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WEBINAR INFORMATION – HOUSEKEEPING RULES



- **‘Chat’ box:** please use this for general requests and for interactive activities.
- **‘Q&A’ box:** please use this to send questions to the panelists.
(We will answer these during the discussions)

***Please Note:** Attendees’ microphones are muted. We cannot respond to ‘Raise Hand’.*

AGENDA

- **Introduction to the webinar and Housekeeping**
Erika Varga, IWA Climate Smart Utilities (CSU)
- **Scope and Objectives**
Ahlem Filali, INRAE, France
- **Emissions from wastewater treatment processes**
Romain Lemaire, Veolia, France
- **Other emission sources**
Ahlem Filali, INRAE, France
- **Conclusions and perspectives**
Mathieu Sperandio, INSA Toulouse / TBI, France
- **Closing remarks**
Erika Varga, IWA Climate Smart Utilities (CSU)

CLIMATE SMART UTILITIES – GHG MONITORING

- Established in 2021
 - Focus: having a shared tool and approach for GHG monitoring
- Community of practice
 - Publications
 - Webinars
 - Monthly calls



CLIMATE SMART UTILITIES – GHG MONITORING

- Join us: <https://www.iwaconnectplus.org/group/feeds?CommunityKey=a0M4K000004Pd5YUAS>



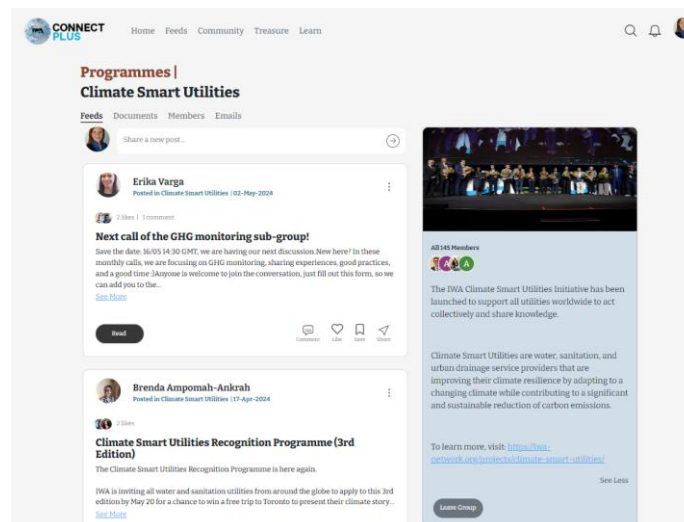
Amanda Lake
Jacobs



Jürgen Schmidtke
*Stadtenwässerung
Stuttgart*



Erika Varga
CSU



Brenda Ampomah-Ankrah
IWA



Samuela Guida
IWA

Sign up to join the
IWA Climate Smart
Utilities GHG group
and be invited here



Open to all!

Advancing N₂O Quantification Toward Mitigation: Insights from France

SCOPE AND OBJECTIVES

Ahlem Filali (PhD), INRAE



Astee

IWA representative in France

Water and Waste Professionals Association

Founded 1905 • ~4,000 professionals from **utilities**, **academia**, **industry** and **public authorities**



GHG Working Group

GHG reporting mandatory since 2012: private companies >500 employees and public bodies >50,000 inhabitants

Publishes **the sector reference guide** for the assessment of GHG emissions from water and wastewater services

Latest edition: **2024**

N₂O Sub-Working Group

Dedicated to improving N₂O emission estimates for the French wastewater sector

IPCC default EF — N₂O from BNR processes

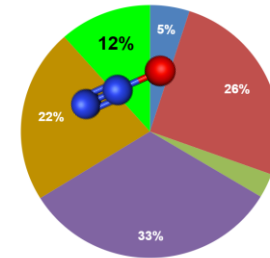
×40

IPCC 2006: **0.035%** of influent TN

IPCC 2019: **1.6%** of influent TN

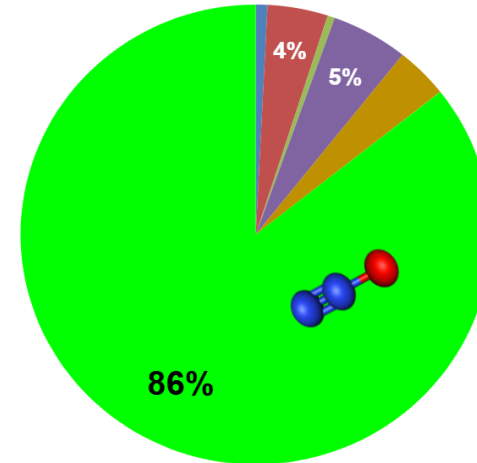
***Tier 2 approach:** IPCC encourages countries with sufficient and reliable measurement data to develop their own country-specific emission factors*

Carbon footprint — Example of a French WRRF



EF = 0.035% (IPCC 2006)

648 tCO₂/y



EF = 1.6% (IPCC 2019)

3997 tCO₂/y

Polymer FeCl₃ Lime Electricity Transport N₂O

● Refine & Adapt

Develop emission factors adapted to French wastewater treatment practices and technologies

● Understand Drivers

Analyse EF distributions across process types and operating conditions to identify key influencing conditions

● Map Knowledge Gaps

Identify missing data and where future measurements are needed

● Support Mitigation Initiatives

Quantification provides the basis for informed mitigation strategies

Beyond technical updates...

● Share Knowledge

Bridge the gap between research and practice and help practitioners grasp the complexity behind N₂O emissions:

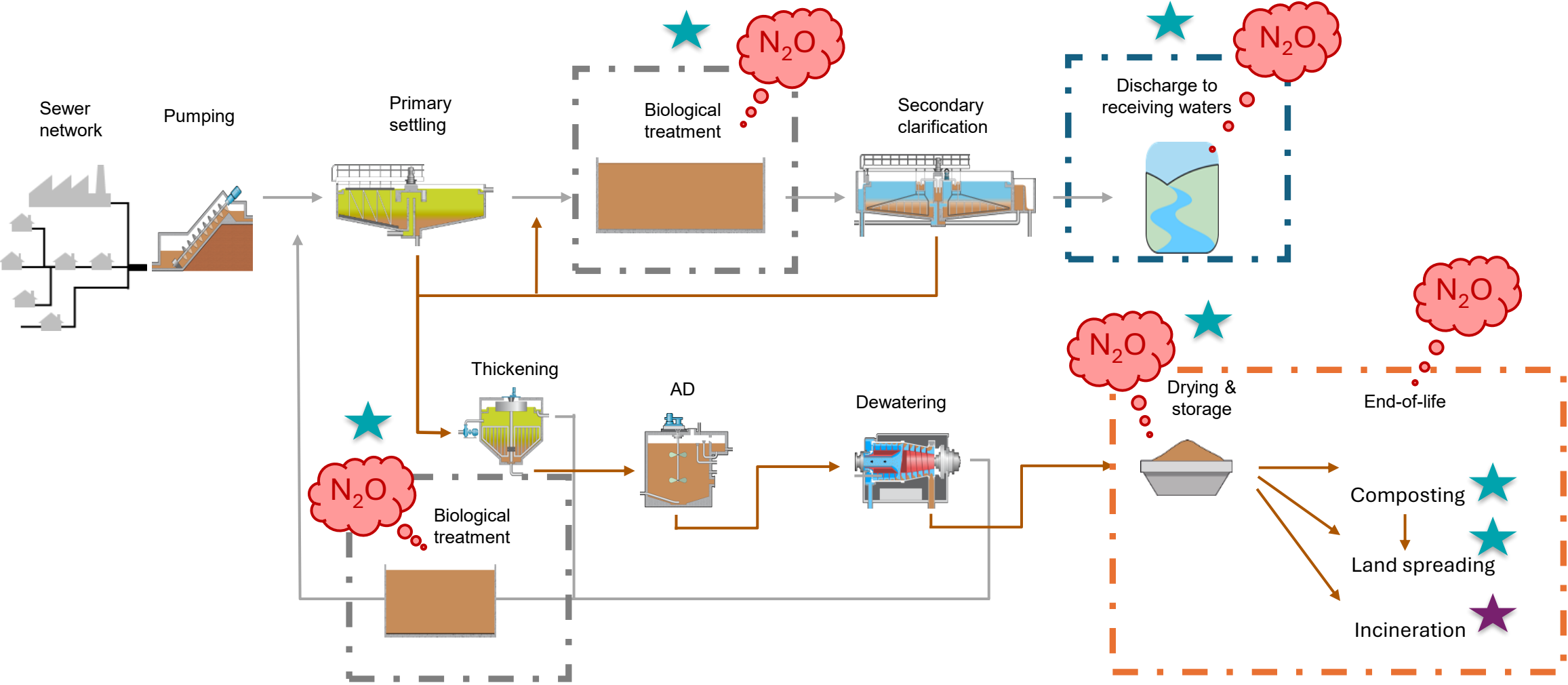
A single emission factor masks a highly variable reality!

Understanding why a plant may deviate from the default is key to meaningful action



Microbial N₂O production pathways

Fuel-N₂O formation pathway



- Wastewater & Reject Water Treatment
- Receiving Waters
- Sludge Handling
- Cross-cutting / Coordination

● **CNRS**

Research

J. Garnier

● ● ● **INRAE**

Research

A. Filali (lead)
A. De Guardia
S. Gillot
M. Pradel
P. Laville

● **INSA-TBI**

Research

M. Sperandio

● **Astee**

Professional association

A. Clifford
M. Brunier
N. Bouthour (Internship student)

● **SIAAP**

Water utility

S. Azimi
S. Guérin
R. Krimou

● ● **SUEZ**

Industry

R. Aimoz
A. Gonzalez Ospina
S. Orlik
F. Pierre
D. Snidaro

● ● **VEOLIA**

Industry

E. Gazaniol
R. Lemaire

● **CITEPA**

National GHG inventory

R. Bort

● **Water Cities**

Consulting

C. Trommsdorff



Help from many others:

Astee GHG Working Group | C. Langlois • F. Paillet • N. Smith (SUEZ) | C. Guéguen

PATH A — French data available

Review and validate measurement protocols
through expert consensus



Analyze emissions alongside operating conditions
→ identify key EF drivers



Refined emission factors
Benchmarking against international literature

PATH B — Data gap

Compile emission data from international
sources: peer-reviewed literature,
technical reports, IPCC guidelines,...



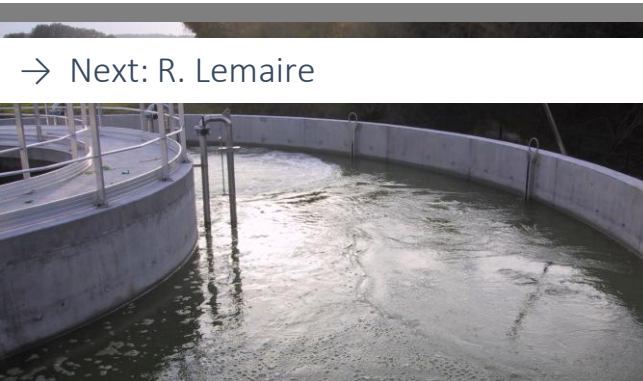
Screen for representativeness: sludge type,
measurement duration and protocols, field conditions,...



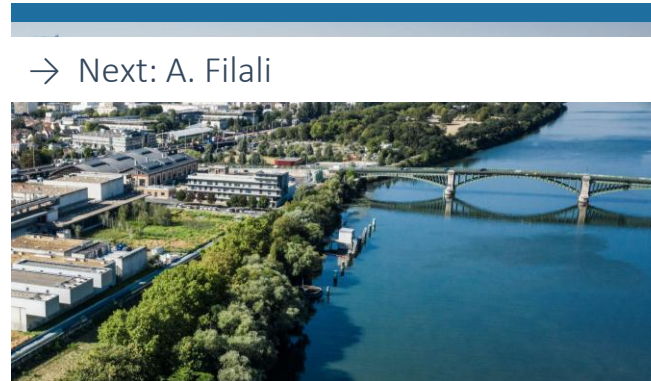
Knowledge gaps mapped
Limited representativeness of available data

3 Technical Fact Sheets

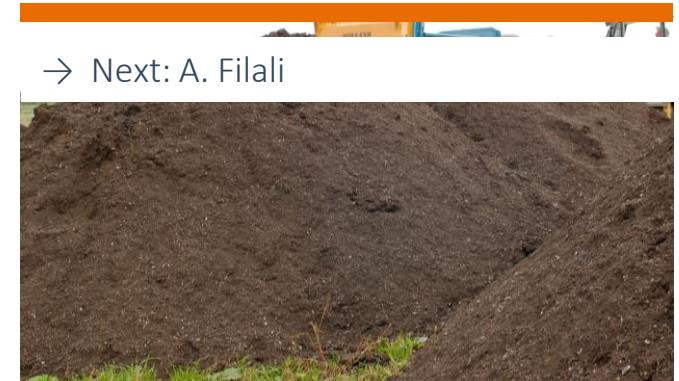
#1 Biological N treatment



#2 Effluent discharge



#3 Sludge handling



Work in progress

Emission factor refinement is an ongoing process
As new data become available, emission factors
will continue to evolve...

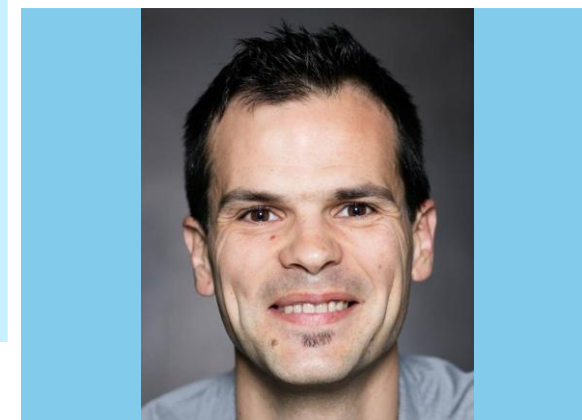
Conclusion & Perspectives

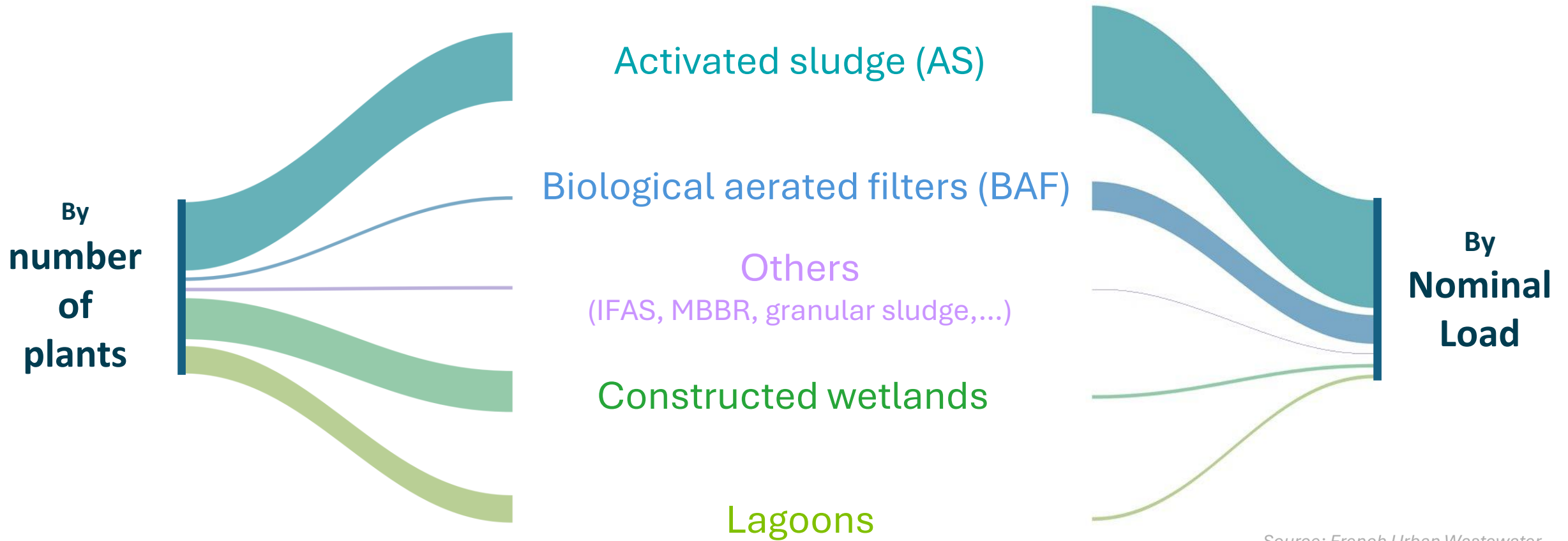
→ Next: M. Sperandio

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EMISSIONS FROM WASTEWATER TREATMENT PROCESSES

Romain Lemaire (PhD), VEOLIA



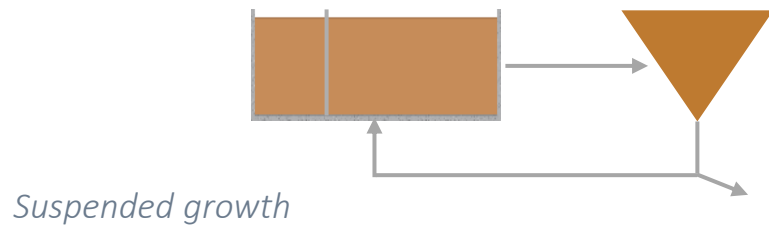


Source: French Urban Wastewater Database (BDERU)

Focus: Activated Sludge & BAF, treating the bulk of the pollution load

8

Activated sludge



Low-loaded, continuous feeding

Configuration

NDN

Applied load

10 – 80%

of design capacity

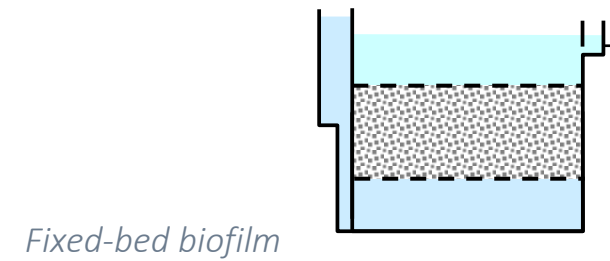
N volumetric load

0.04 – 0.08

kgN/m³/d

6

Biological Aerated Filters



High-rate, continuous feeding, periodic backwashing

Configuration

CN, NDN, N

Applied load

63 – 100%

of design capacity

N volumetric load

0.5 – 1.2

kgN/m³_{media}/d

CN = Carbon removal & Nitrification

NDN = Nitrification & Denitrification

N = Nitrification

N_2O is generated during nitrification/denitrification
Only nitrogen that is biologically converted can produce N_2O

IPCC Approach

$$\text{EF} = \% \text{TKN}_{\text{influent}}^*$$

$$\text{N}_2\text{O} = \text{TKN}_{\text{influent}} \times \text{EF}$$

Does not distinguish between nitrogen that is biologically converted or not

*TKN $\approx$ TN at WRRF inlet

Our Approach

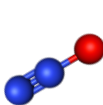
$$\text{EF} = \% \text{TKN}_{\text{removed}}$$

$$\text{N}_2\text{O} = \text{TKN}_{\text{influent}} \times \text{TKN Removal} \times \text{EF}$$

- ✓ Isolates the main producing pathway
- ✓ Improves comparability between WRRFs and BNR technologies

TKN removed provides a **generalizable** basis across treatment configurations

Working hypotheses: **100 kg TKN influent/d**



 **N₂O: 1 kg N₂O-N/d**

Case 1 — Nitrif. + Denitrif.

TKN (NH₄⁺ + N_{org.}) → NO₃⁻ → N₂ (80%)

TKN removed: **95 kg N/d**
TN removed: **80 kg N/d**

Emission factor by denominator

EF / TKN influent (IPCC)	1.0%	✓
EF / TN removed	1.3%	✓
EF / TKN removed (Our approach)	1.1%	✓

 **N₂O: 1 kg N₂O-N/d**

Case 2 — C + Nitrification

TKN (NH₄⁺ + N_{org.}) → NO₃⁻ (95%)

TKN removed: **95 kg N/d**
TN removed: **10 kg N/d**

Emission factor by denominator

EF / TKN influent (IPCC)	1.0%	✓
EF / TN removed	10.0%	✗
EF / TKN removed (Our approach)	1.1%	✓

 **N₂O: 0 kg N₂O-N/d**

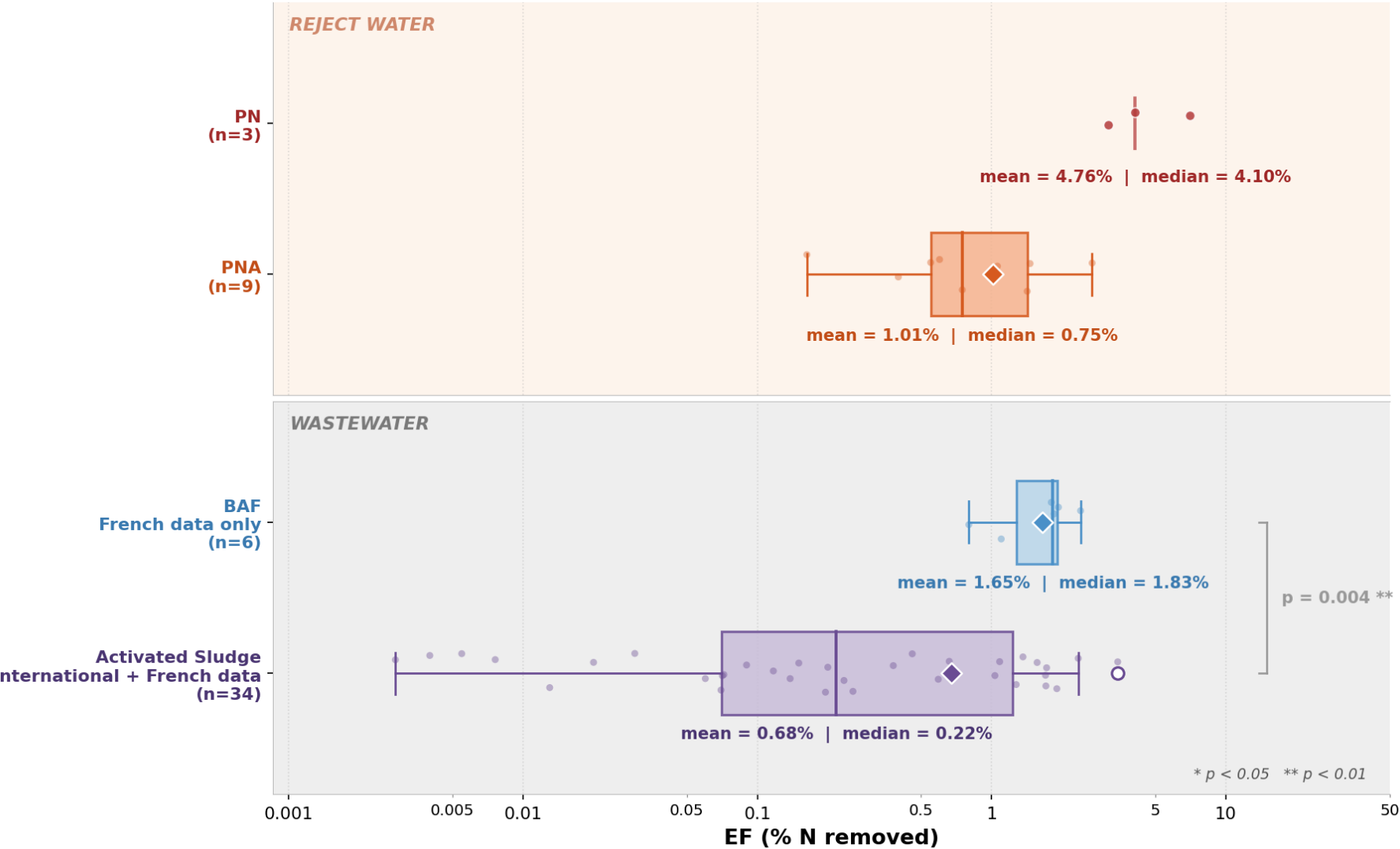
Case 3 — C removal only

assimilation only (~10%)

TKN removed: **10 kg N/d**
TN removed: **10 kg N/d**

Emission factor by denominator

EF / TKN influent (IPCC)	1.0% → 1 kg N/d	✗
EF / TN removed	1.0% → 0.1 kg N/d	✓
EF / TKN removed (Our approach)	1.0% → 0.1 kg N/d	✓

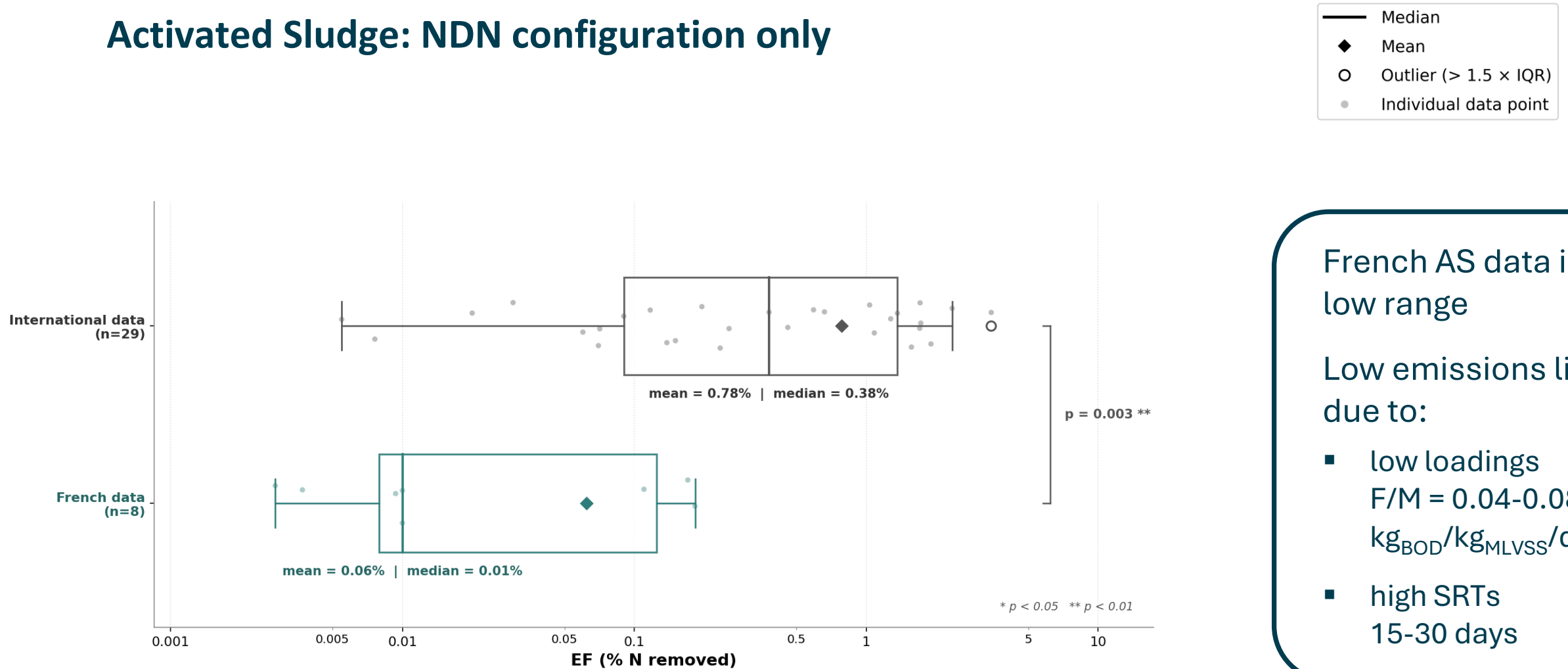


EFs increase with nitrification intensity: **BAF > AS**, **PN > AS**

NO₂⁻ accumulation further amplifies N₂O emissions: **PN > PNA**

N removed is adapted to the treatment type: **TN** for denitrifying processes (NDN, DN); **TKN** for non-denitrifying processes (C, CN, N); **TN** for PNA and **NH₄/TAN** for PN

Activated Sludge: NDN configuration only



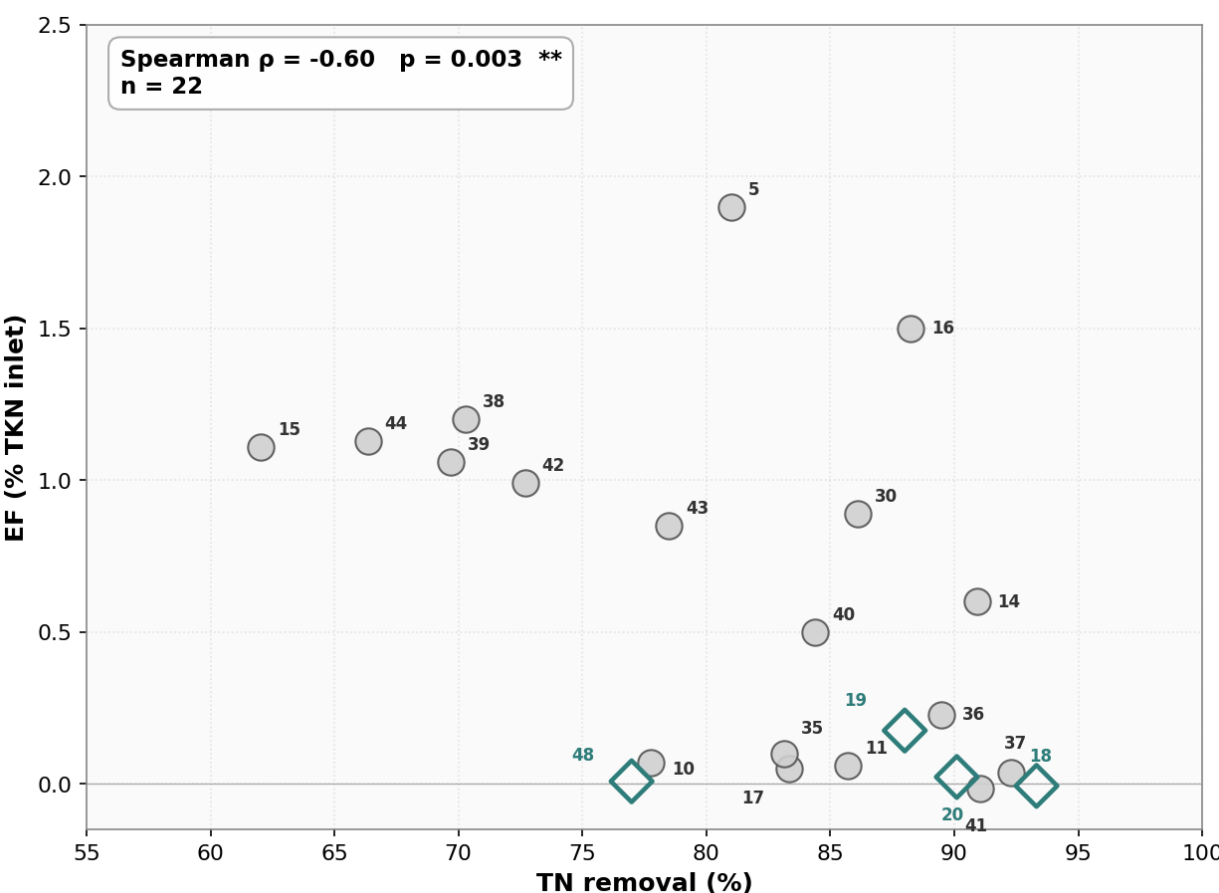
N removed estimated based on **TN** for international data and **TKN** for French data

French AS data in the low range

Low emissions likely due to:

- low loadings
F/M = 0.04-0.08
kg_{BOD}/kg_{MLVSS}/d
- high SRTs
15-30 days

Activated Sludge: NDN configuration only



Studies (ids):

This study

ids: 18, 19, 20, 48

Ahn et al., 2010

ids: 10, 11, 14, 15, 16, 17

Duan et al., 2020

ids: 30

Pan et al., 2016

ids: 5

Valkova et al., 2021

ids: 35, 36, 37, 38, 39, 40, 41, 42, 43, 44

Well-performing denitrification contributes to reducing N₂O emissions

This also explains the low EFs observed in French WRRFs, which typically achieve high TN removal

8

Activated sludge

*Continuous feeding***0.06% TKN removed**

CI95% : 0.02% - 0.11%

CV = 126%*High variability***6**

Biological Aerated Filters

*Continuous feeding***1.65% TKN removed**

CI95% : 1.29% - 1.96%

CV = 36%*Low variability*

Conditions associated with higher N₂O emission risk for AS

PROCESS DESIGN

- SBR
- Partial nitrification
- Carbon-only treatment
- Plug-flow (nitrogen gradients)

OPERATING CONDITIONS

- High fluctuations in incoming N load or NH₄⁺ (e.g. input of reject water)
- Nitrite detection during aerated or non-aerated zones or phases
- Mixed liquor pH far from neutrality (< 6 or > 8)

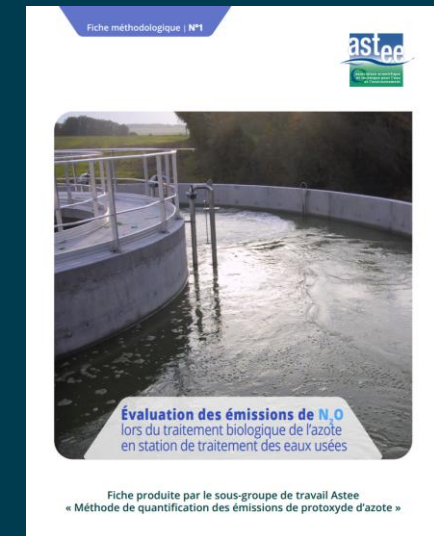
Thanks for your attention

- **Sam Azimi**, SIAAP
- **Noura Bouthour**, ASTEE
- **Ahlem Filali**, INRAE
- **Sylvie Gillot**, INRAE
- **Sabrina Guérin**, SIAAP
- **Romain Lemaire**, VEOLIA
- **Denis Snidaro**, SUEZ
- **Mathieu Sperandio**, INSA - TBI

Special thanks to **Adeline Clifford** and **Marine Brunier** (ASTEE)
for their support to the sub-working group

Technical Fact Sheet

#2



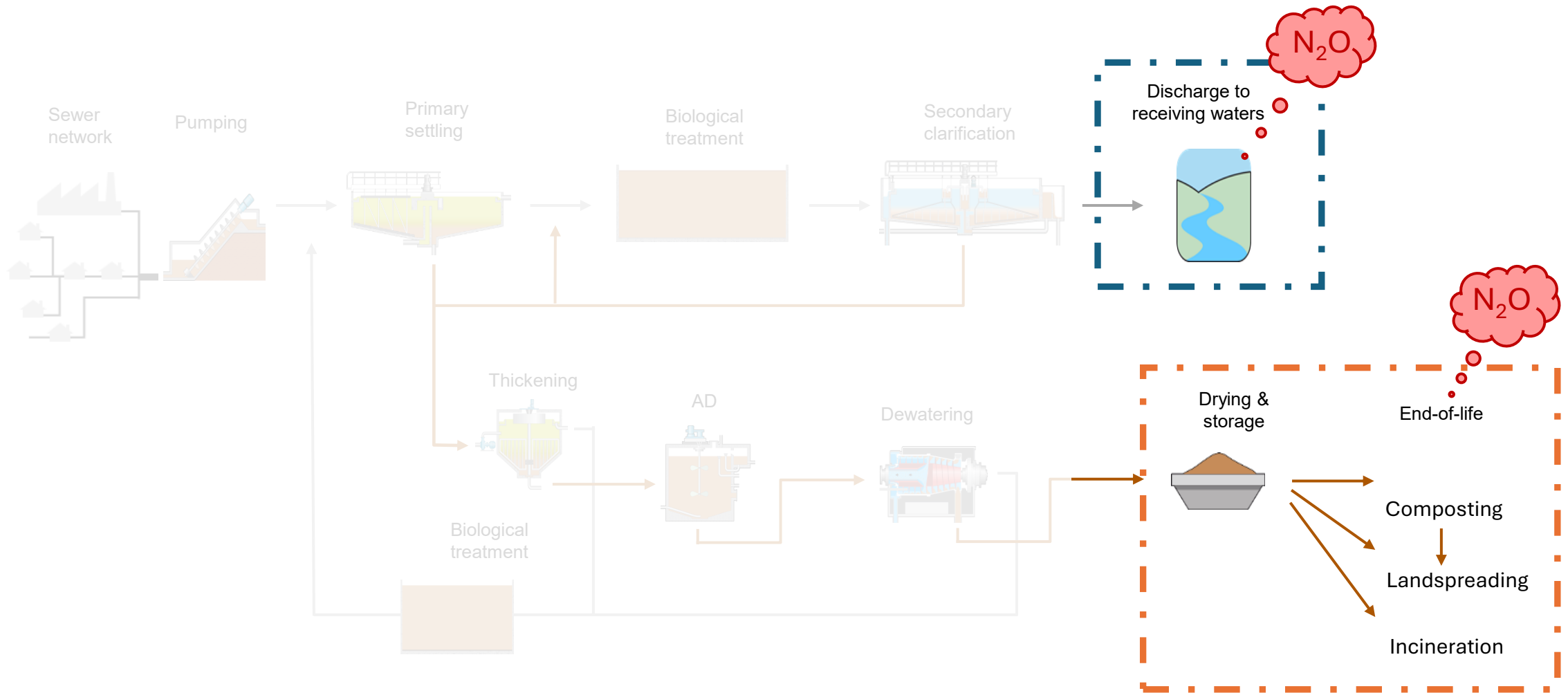
Available at
astee.org/publications

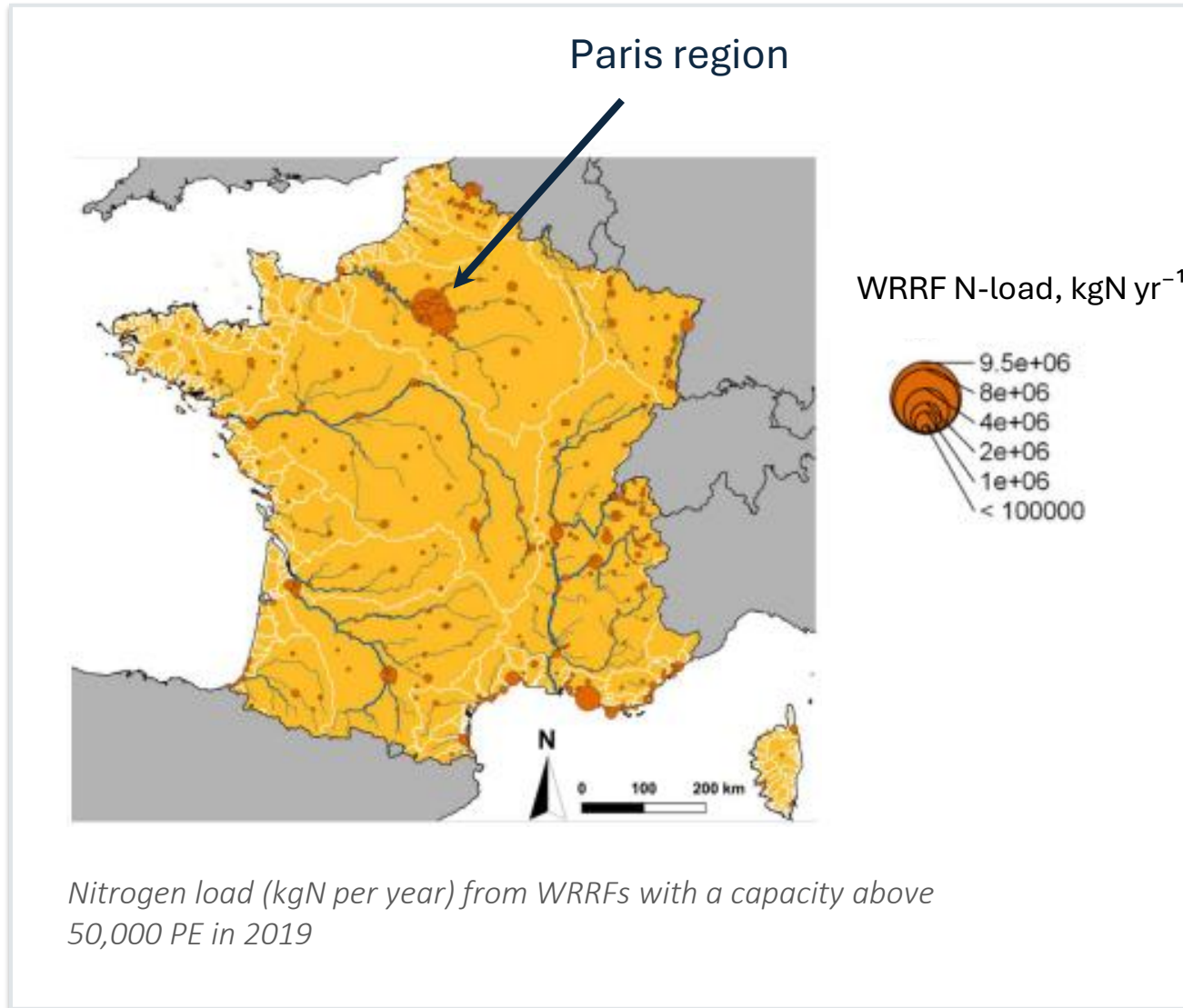
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OTHER EMISSION SOURCES

Ahlem Filali (PhD), INRAE





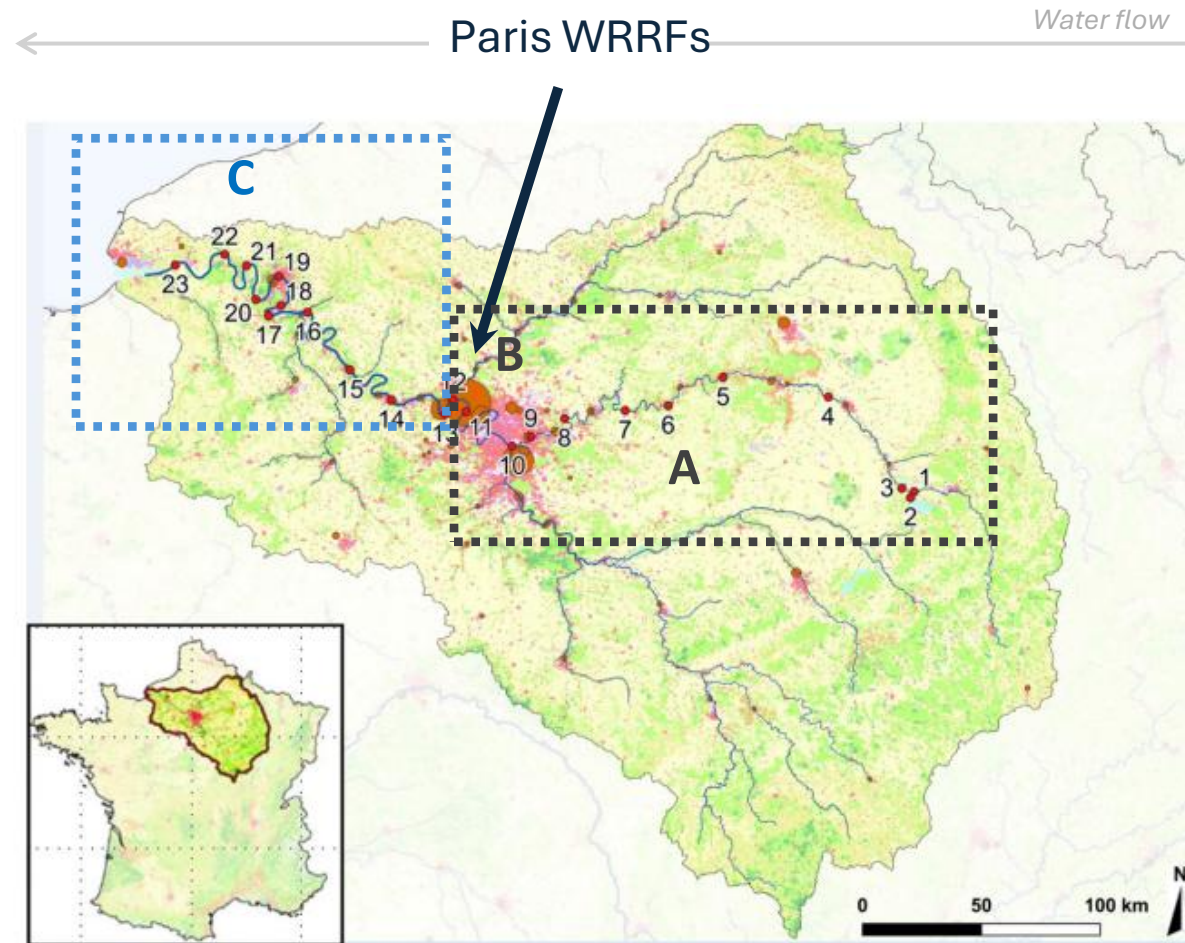


Multiple nitrogen sources

WRRFs are not the only anthropogenic source of nitrogen in surface waters: agriculture, livestock, and groundwater-sediment exchanges also contribute

Paris region: a major hotspot

The Paris region (12 million habitants) concentrates a significant share of the nitrogen load discharged to surface waters



Data: sampling campaigns between 1998 and 2007 along the Marne River and the main axis of the lower Seine
(Garnier et al., 2009 – Agriculture, Ecosystems & Environment)

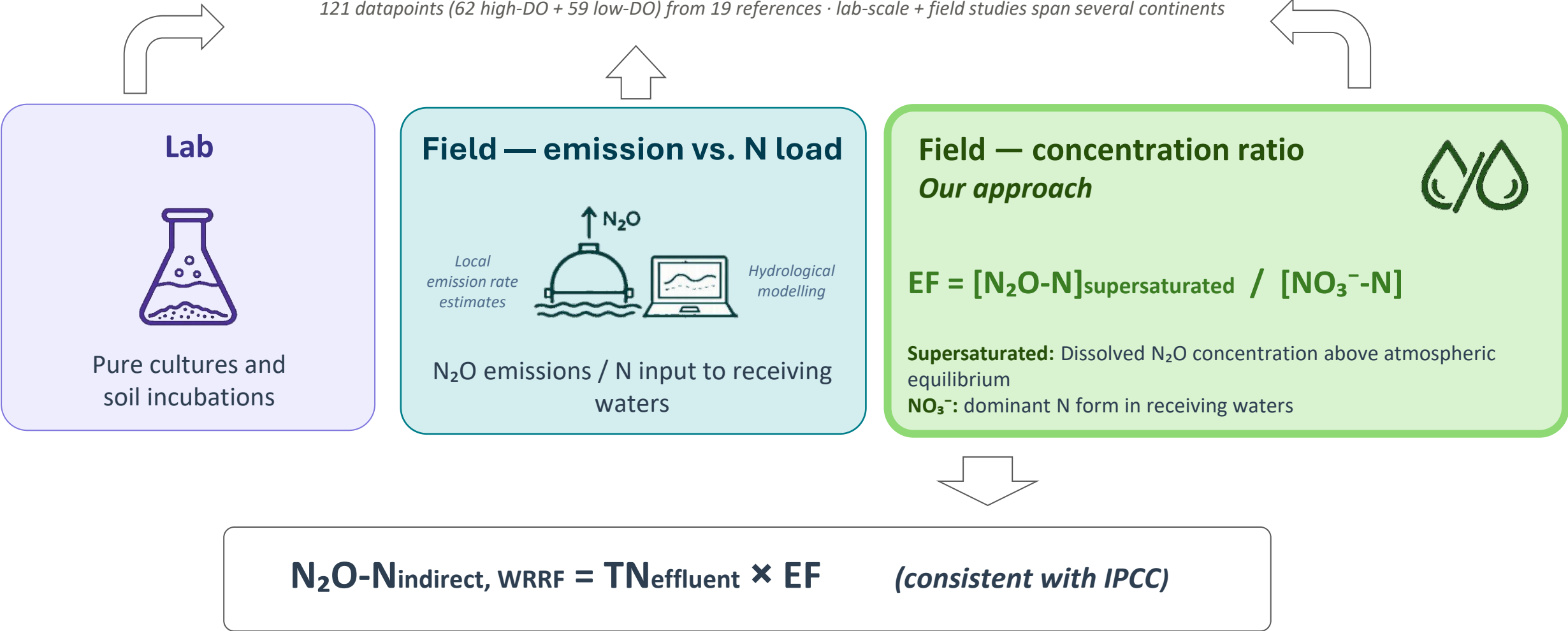
Data selection

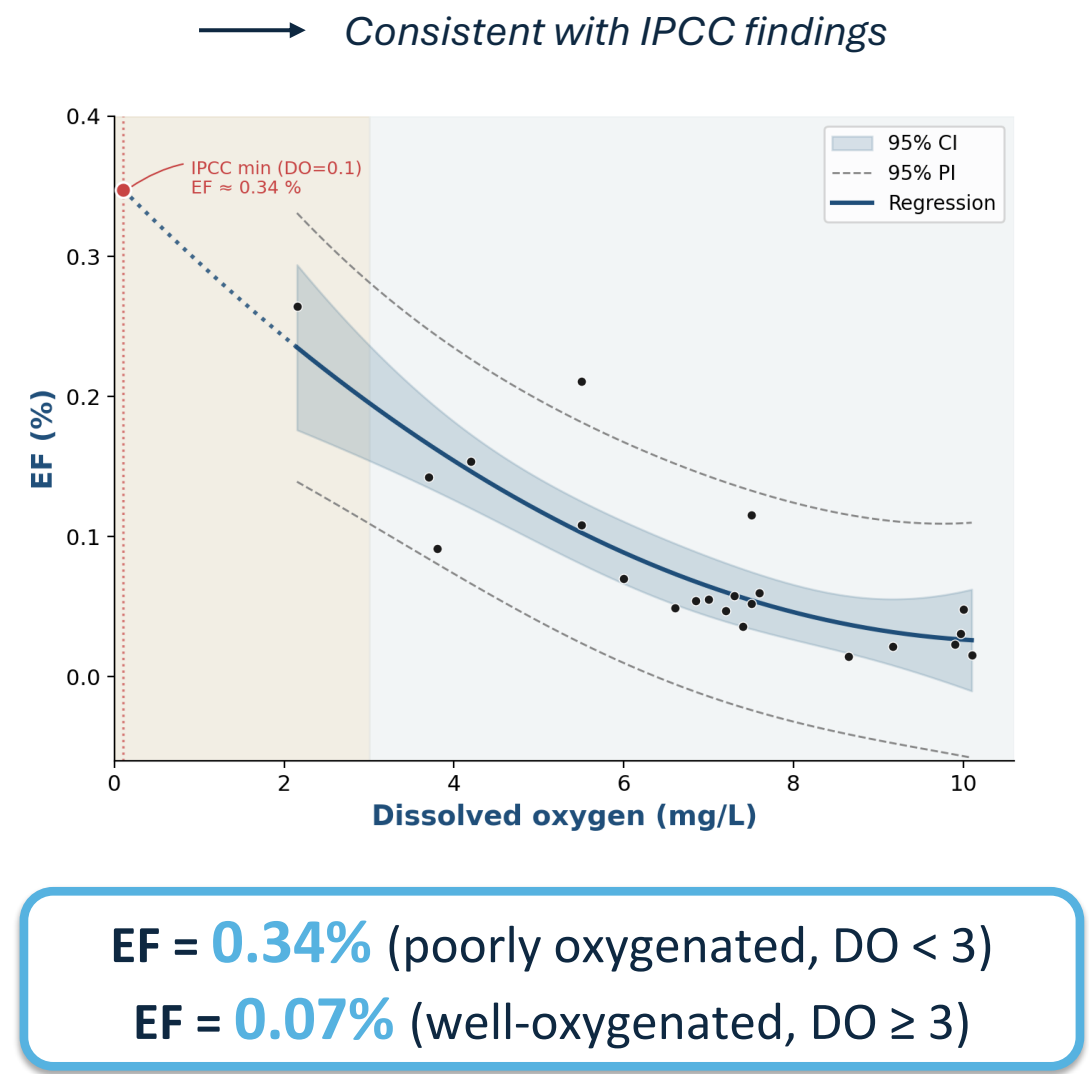
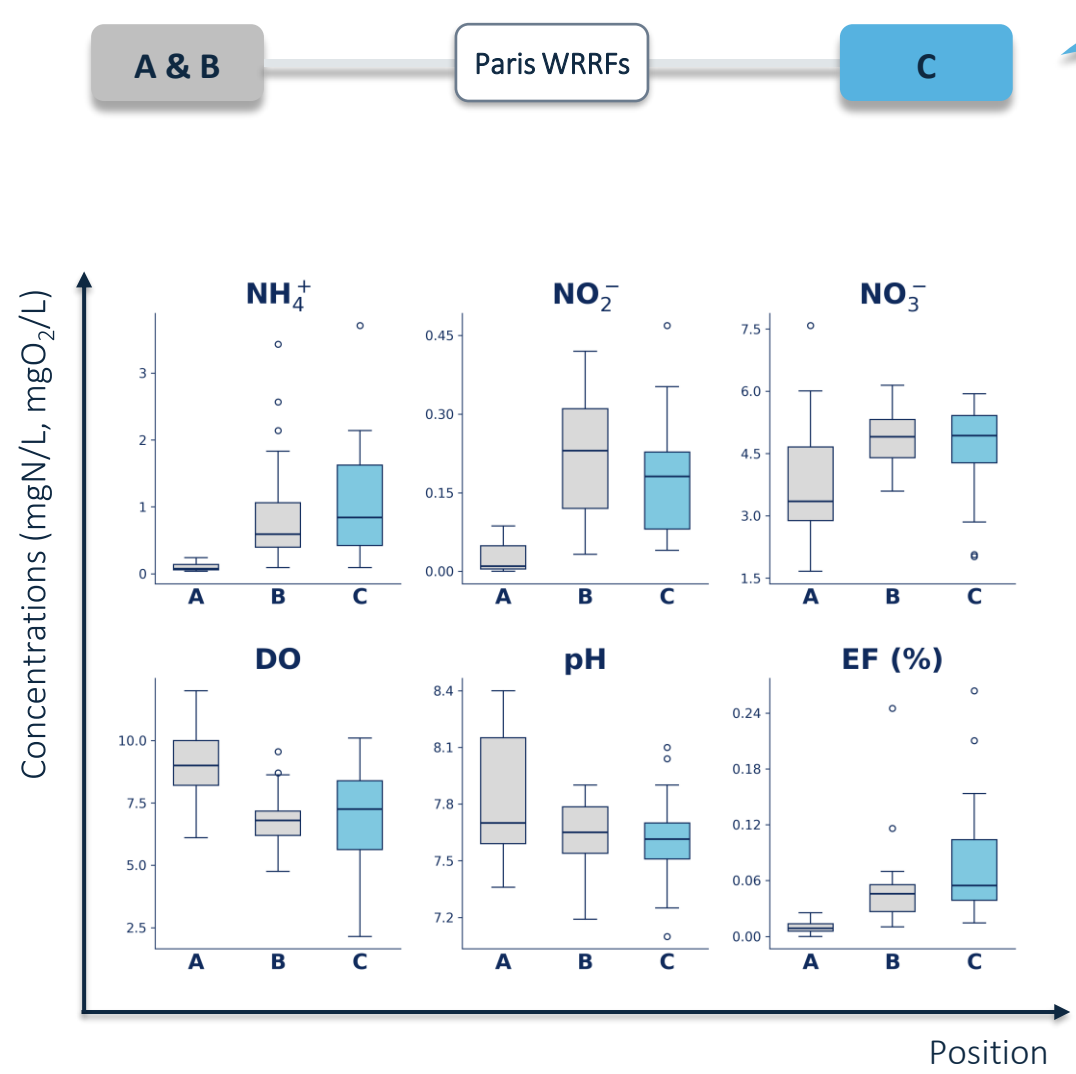
A & B — Upstream of Paris WRRFs
Shown for comparison

C — Downstream of Paris WRRFs
→ Used for emission factor revision (n=21 data)

Default IPCC-EFs for receiving waters

121 datapoints (62 high-DO + 59 low-DO) from 19 references · lab-scale + field studies span several continents







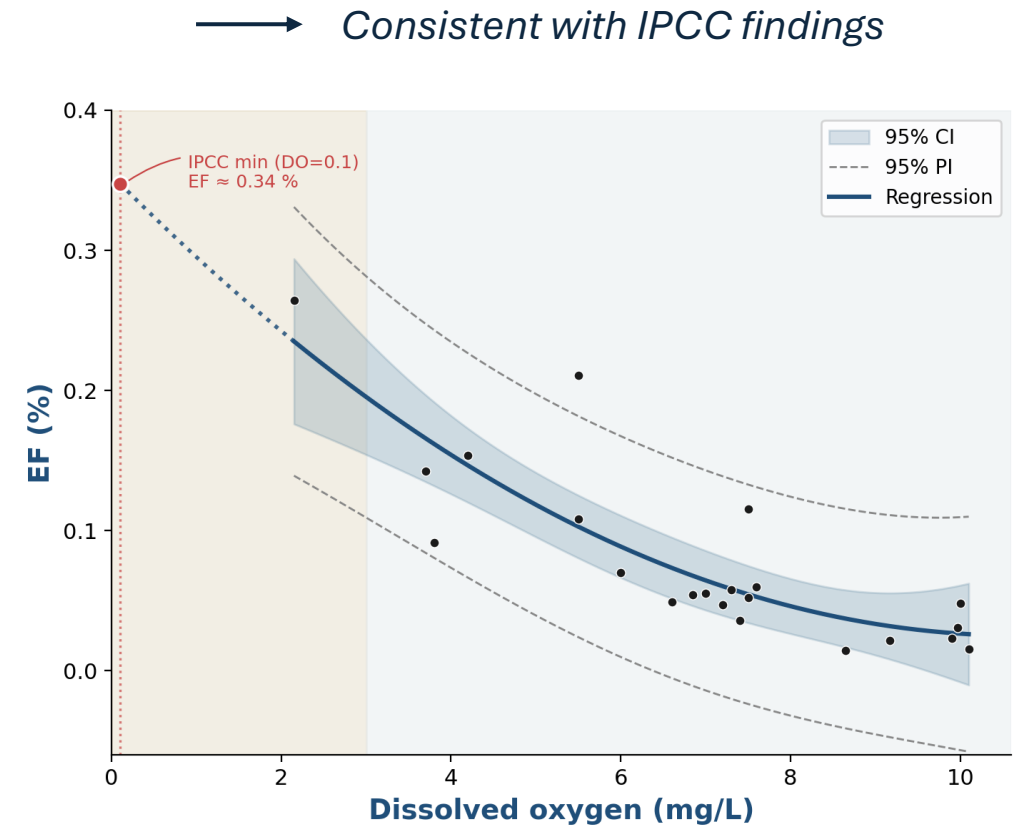
Freshwater vs. marine discharges

Same EF applied regardless of water body type
→ **No separate EF for estuarine or coastal zones**



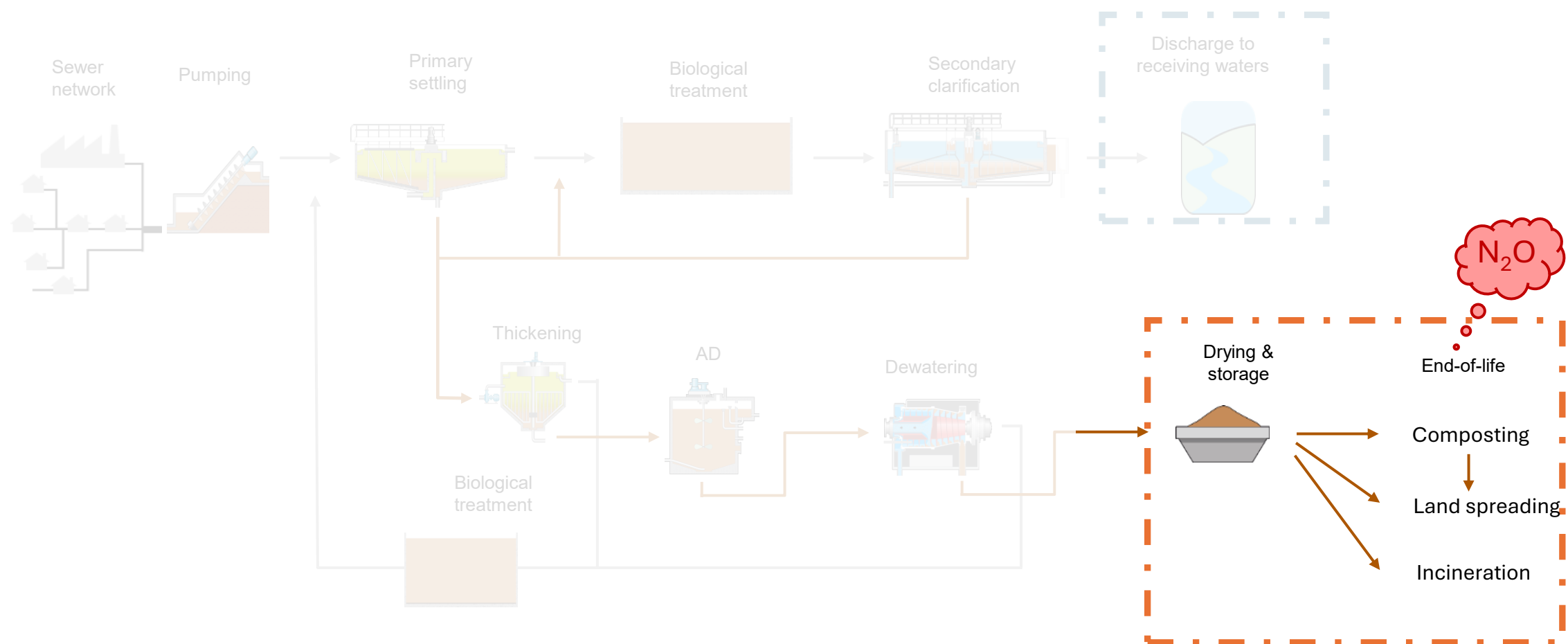
Wet-weather overflows (CSOs)

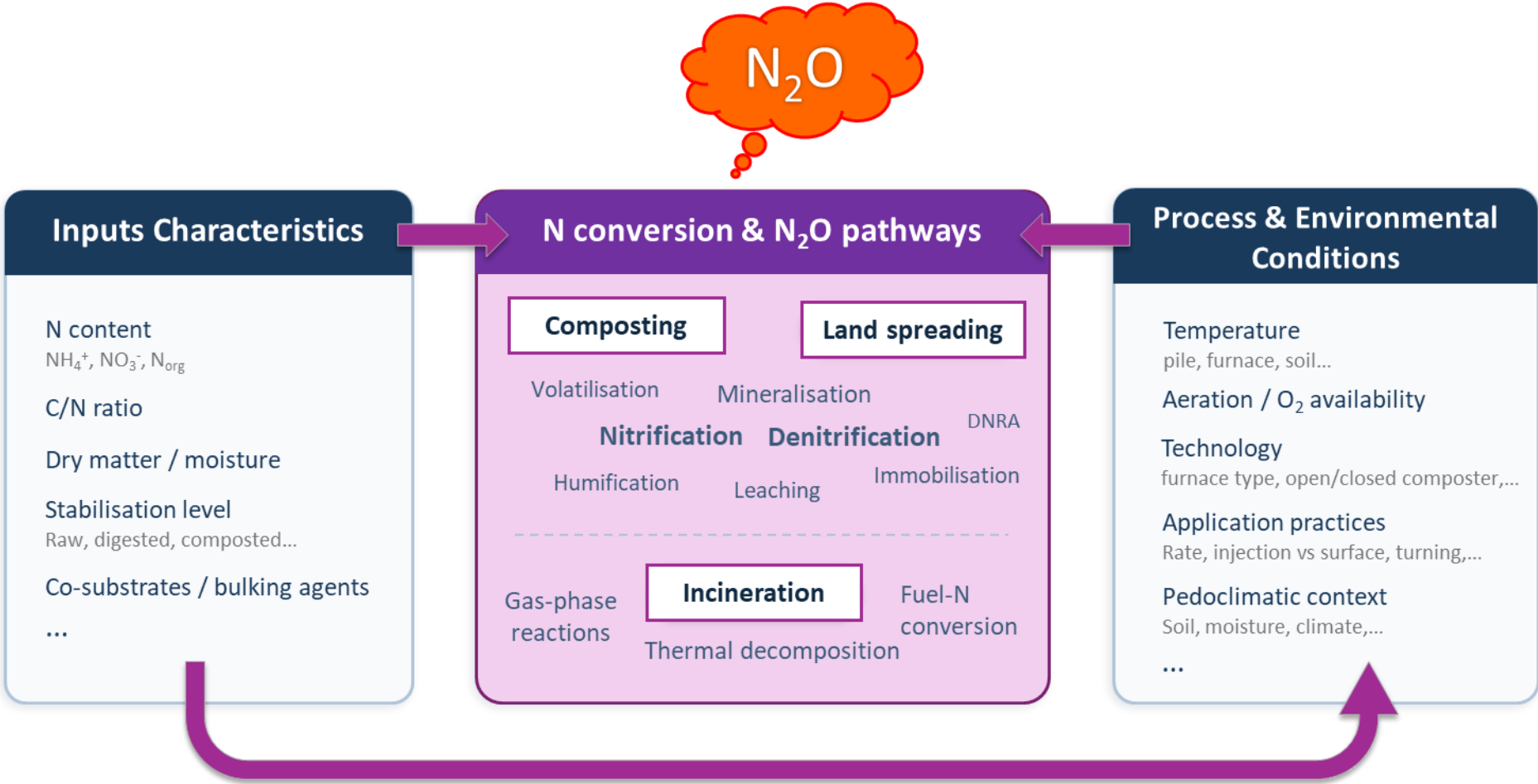
No specific EF for CSO discharges
→ **Treated-water EF applied by default**



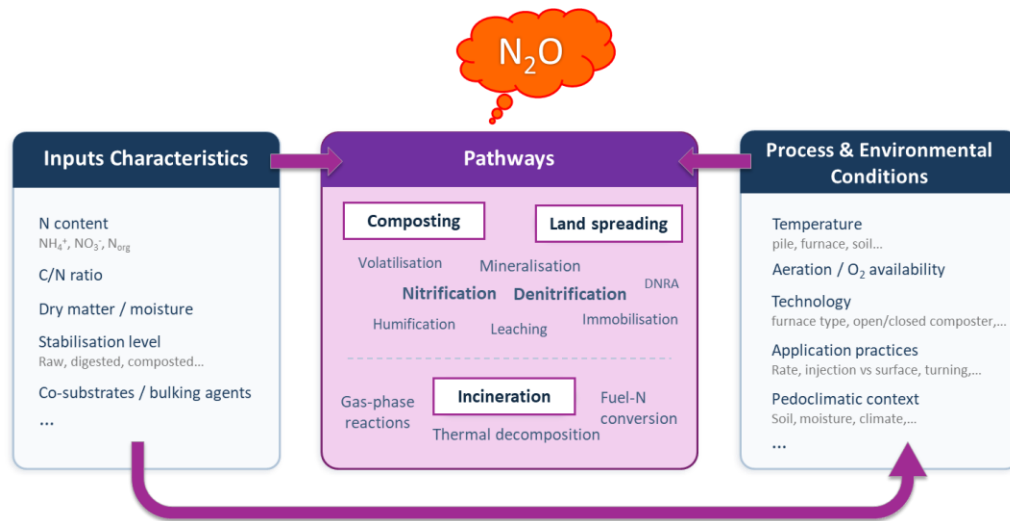
EF = **0.34%** (poorly oxygenated, DO < 3)

EF = **0.07%** (well-oxygenated, DO ≥ 3)





⚠ Non-exhaustive, illustrative list of parameters across composting, land spreading and incineration. Not all parameters apply to each pathway



✓ N₂O production pathways: complex, but increasingly understood (isotope tracing, microbial community analysis, selective inhibitors)

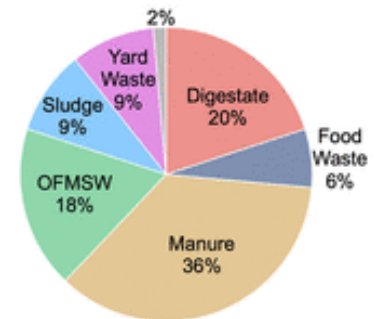
✓ Influence of substrate properties and management practices on N₂O emissions: increasingly documented

✗ Sewage sludge: largely underrepresented in N₂O emission studies

Nordahl et al. (2023)

46 studies, 140 scenarios

9% sludge and most of the data from lab-scale studies

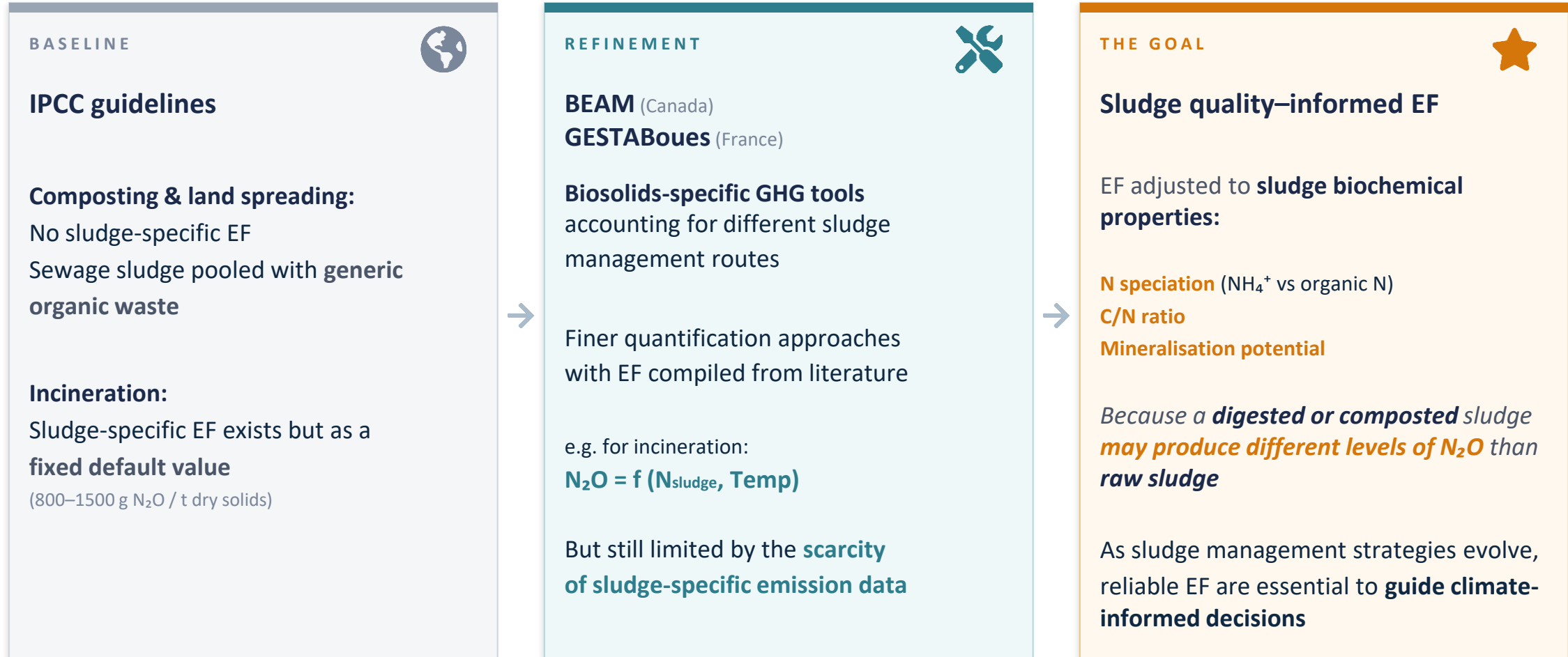


✗ Reliable and representative N₂O emission data for sludge composting and land spreading are lacking...

→ Diffuse source · open air · weeks to months · high spatio-temporal variability

✓ ...unlike sludge incineration, for which measurements exist from industrial-scale furnaces

→ Channeled source · single emission point · controlled operating conditions



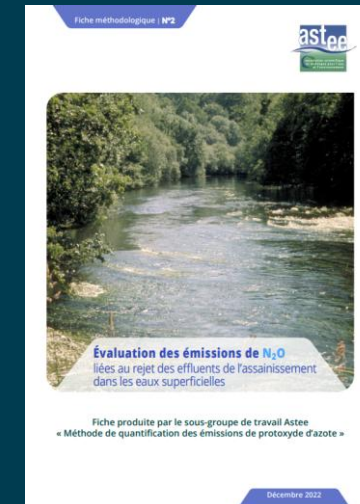
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- **Josette Garnier**, CNRS
- **Romain Aimoz**, SUEZ
- **Amaury De Guardia**, INRAE
- **Cédric Langlois**, SUEZ
- **Patricia Laville**, INRAE
- **Frédéric Pierre**, SUEZ
- **Marilys Pradel**, INRAE
- **Nolwenn Smith**, SUEZ

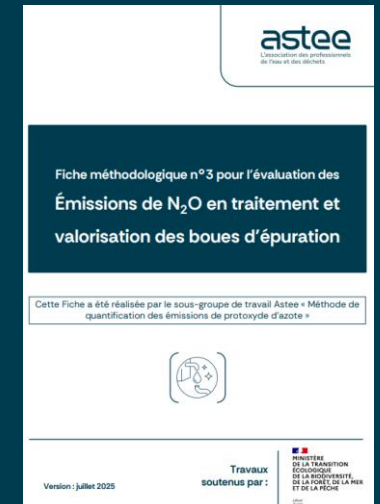
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Technical Fact Sheet

#2



#3



Available at

#2

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#3

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CONCLUSIONS AND PERSPECTIVES

Mathieu Sperandio (Prof.), INSA Toulouse-TBI



THE FRENCH INITIATIVE



astee
L'association des professionnels
de l'eau et des déchets

14 WRRFs

- **low-loaded activated sludge (0.06% TKN removed)**
- **nitrifying BAFs (1.65% TKN removed)**

Implications:

- ▶ **Refine emission factors** — adapted to national treatment practices and technologies
- ▶ **Acknowledge dispersion** — no universal driver, trends emerge rather than predictors
- ▶ **Support action** — a rational starting point for site-specific monitoring and mitigation

EXAMPLES OF OTHER INITIATIVES

USA

Ahn et al. 2010 (12 WRRFs)

0.01 – 1.8% TKN_{inlet}

Denmark NI

Danish EPA (9 WRRFs)

Aggregated EF, 0.84% TN_{inlet}

Switzerland NI

Gruber et al. 2021 (WRRFs: 10 CH, 2 DK, 1 NL and 1 FI)

Stratified by treatment type 0.1-8 / 1.8 / 0.9% TN_{inlet}
by C / N / NDN

Austria NI

Valkova et al. 2021 (10 WRRFs)

Regression model by TN removal degree

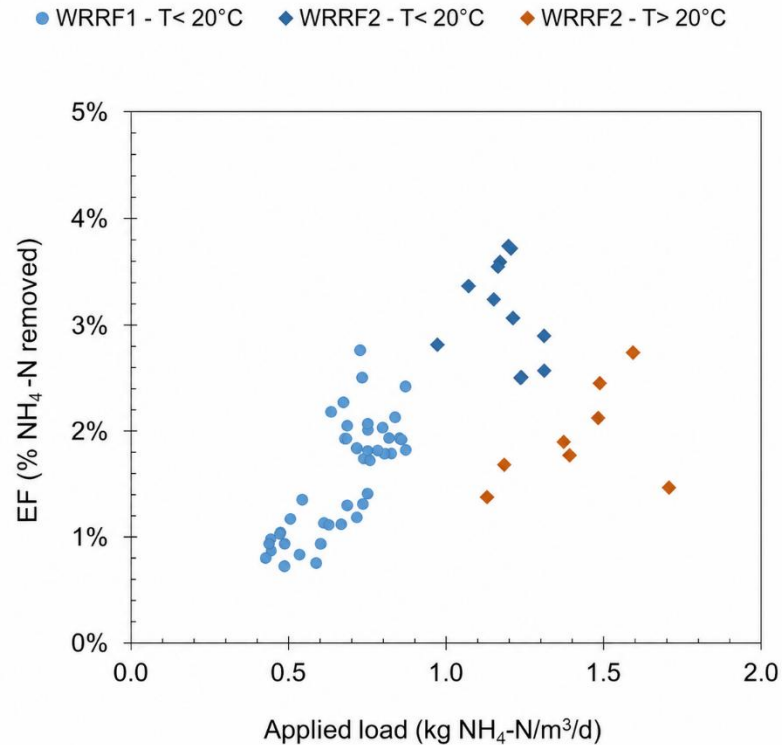
Finland

Sieranen et al. 2024 (6 WRRFs)

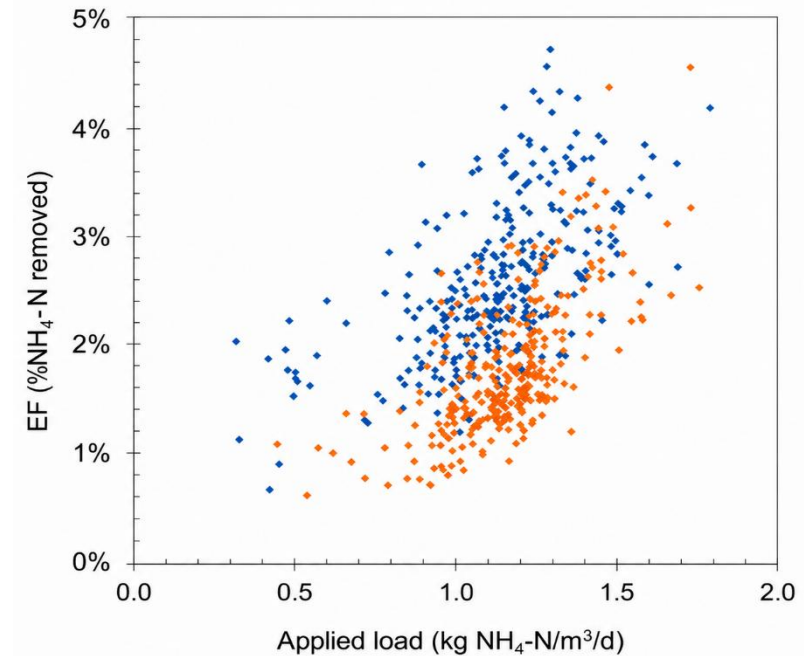
0 – 1.8% TN_{inlet} (strong seasonal contrast)

NI used in national GHG inventory

- High emission factors are related to high loading rates



(Pageot et al., 2024)

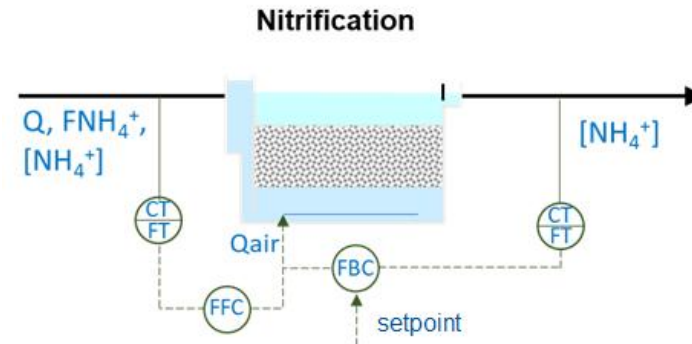


(Fiat 2019)

Mitigation: Guidelines for BAF Control?

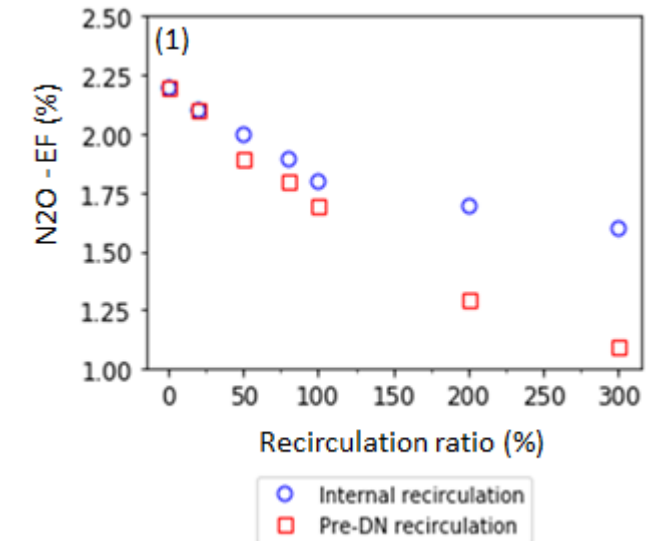
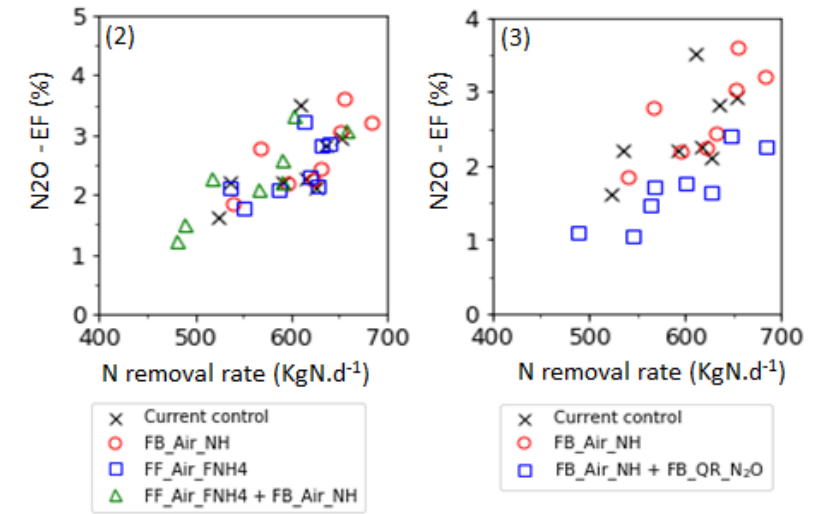
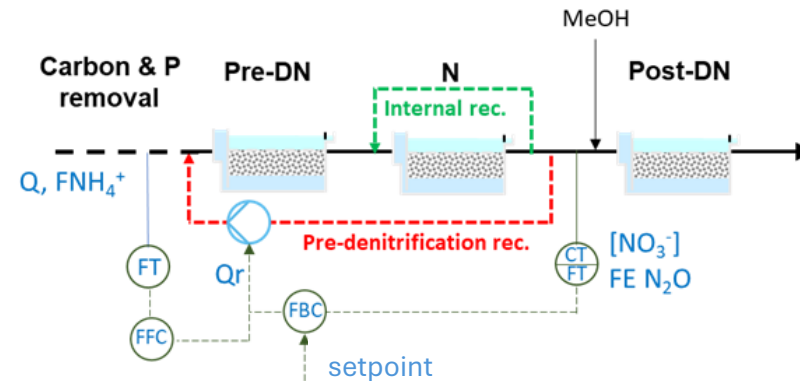
■ Aeration control with ammonium measurement:

- Feedback (FBC)
- Feedforward (FFC)
- FBC + FFC



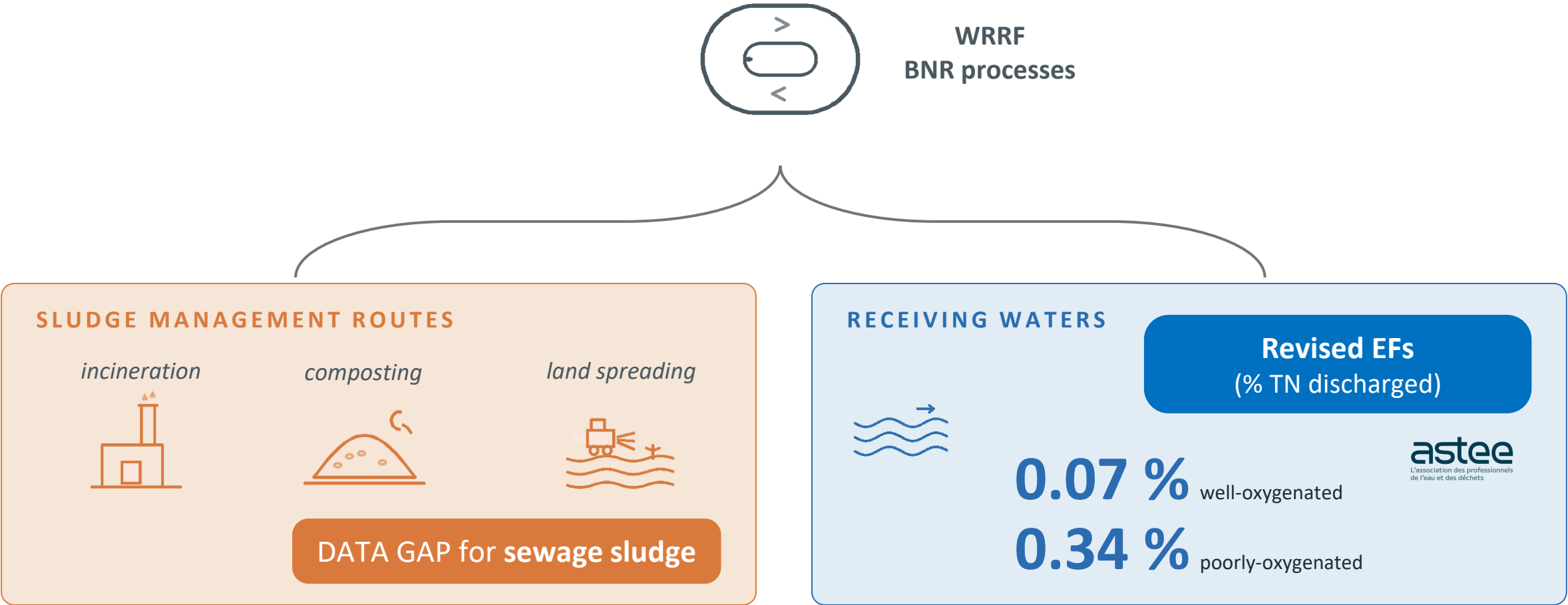
■ Recirculation control with flow, ammonium, N₂O measurements

- Feedback (FBC)
- Feedforward (FFC)
- FBC + FFC



(Gonzales 2021)

GHG emissions unfold along a continuum: **from the treatment plant to the receiving environment**



FILLING SOME GAPS

New data

- ▶ **Sludge management**
Incineration, composting
- ▶ **BNR processes**
More activated sludge, IFAS, BAFs

ANALYSIS

Finer scale

- ▶ From campaign to daily averages
- ▶ Site-specific or shared triggers?

ADOPTION

National inventory

- ▶ Peer-reviewed publication
- ▶ Refined EFs require equally refined activity data



Definition of water sector decarbonisation scenarios to 2050, including N₂O emissions

*A parallel sub-WG on **CH₄** has been launched*

More to come...

CLIMATE SMART UTILITIES – GHG MONITORING

Sign up to join the
IWA Climate Smart
Utilities GHG group
and be invited here



Open to all!

UPCOMING IWA WEBINARS & EVENTS



WEBINAR

**Emerging Advanced Oxidation and
Reduction Processes for Water
Treatment**
– Overview, Potential Applications,
State of Implementation

 **19 May 2026**
13:00 BST

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WEBINAR

**Inspiring the Next Wave of
Water Stewards:
Introducing the AWS
Standard V3.0**

 **27 May 2026**
14:00 BST

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