A critical review of the future trends and perspectives for the implementation of Anammox in the main line of municipal WWTPs

Universitat de Barcelona

Departament d'Enginyeria Química

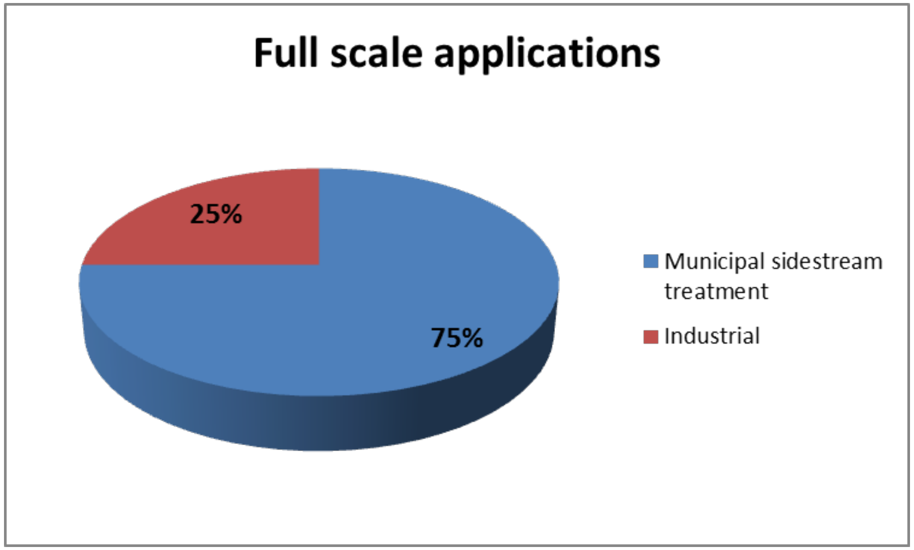
I. Fernández*, J. Dosta, J. Mata-Álvarez
isaac.fernandez@ub.edu

IWWATV

Industrial Waste & Wastewater Treatment & Valorisation

1. Introduction
2. Strategies to maximize C energy recovery from municipal wastewaters
3. Low strength and low temperature wastewaters
4. Effective retention of Anammox biomass
5. One-step vs two-steps systems
6. Conclusions

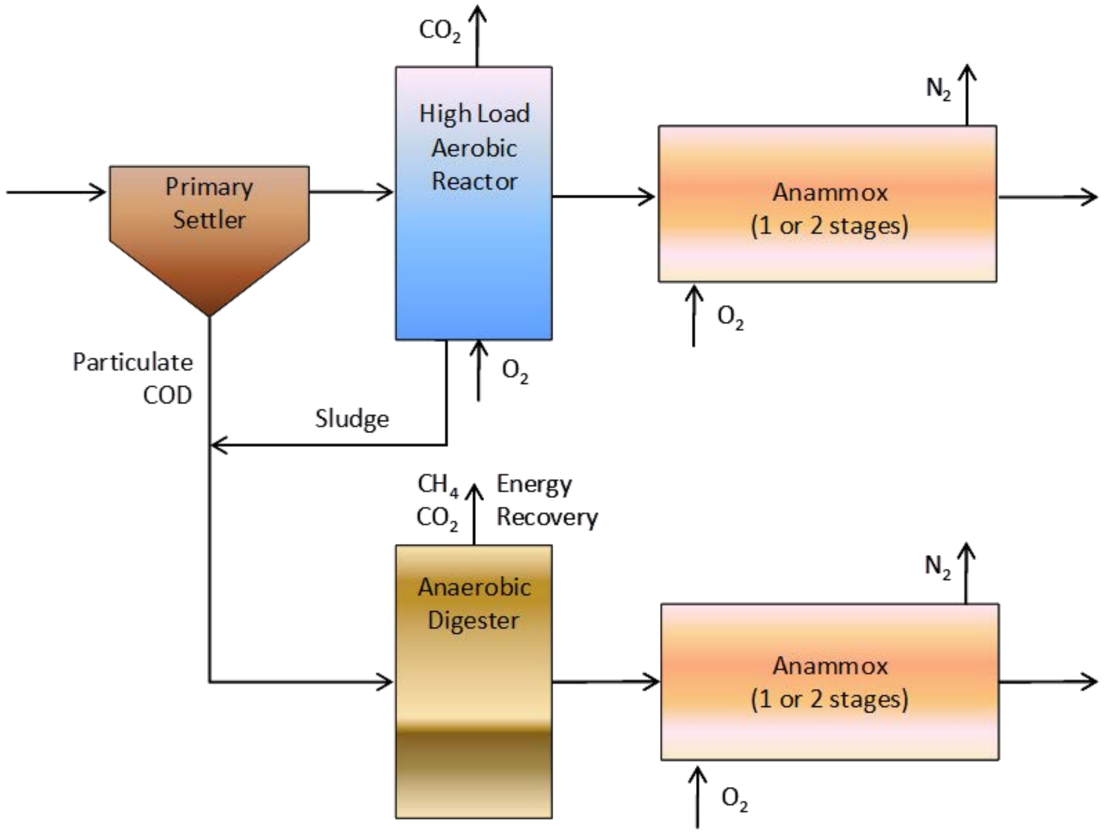
Worldwide full size implementation of PN/Anammox



- More than 100 full scale plants worldwide (2014)
- Almost all treating high strength wastewaters
  - Typical loads 0.5-2 kg N/m^3 d
  - Typical [NH_4^+] about 1 g N/L
- All PN/Anammox at municipal WWTPs treating sidestream

Full scale application of PN/Anammox virtually restricted to low C/N wastewaters

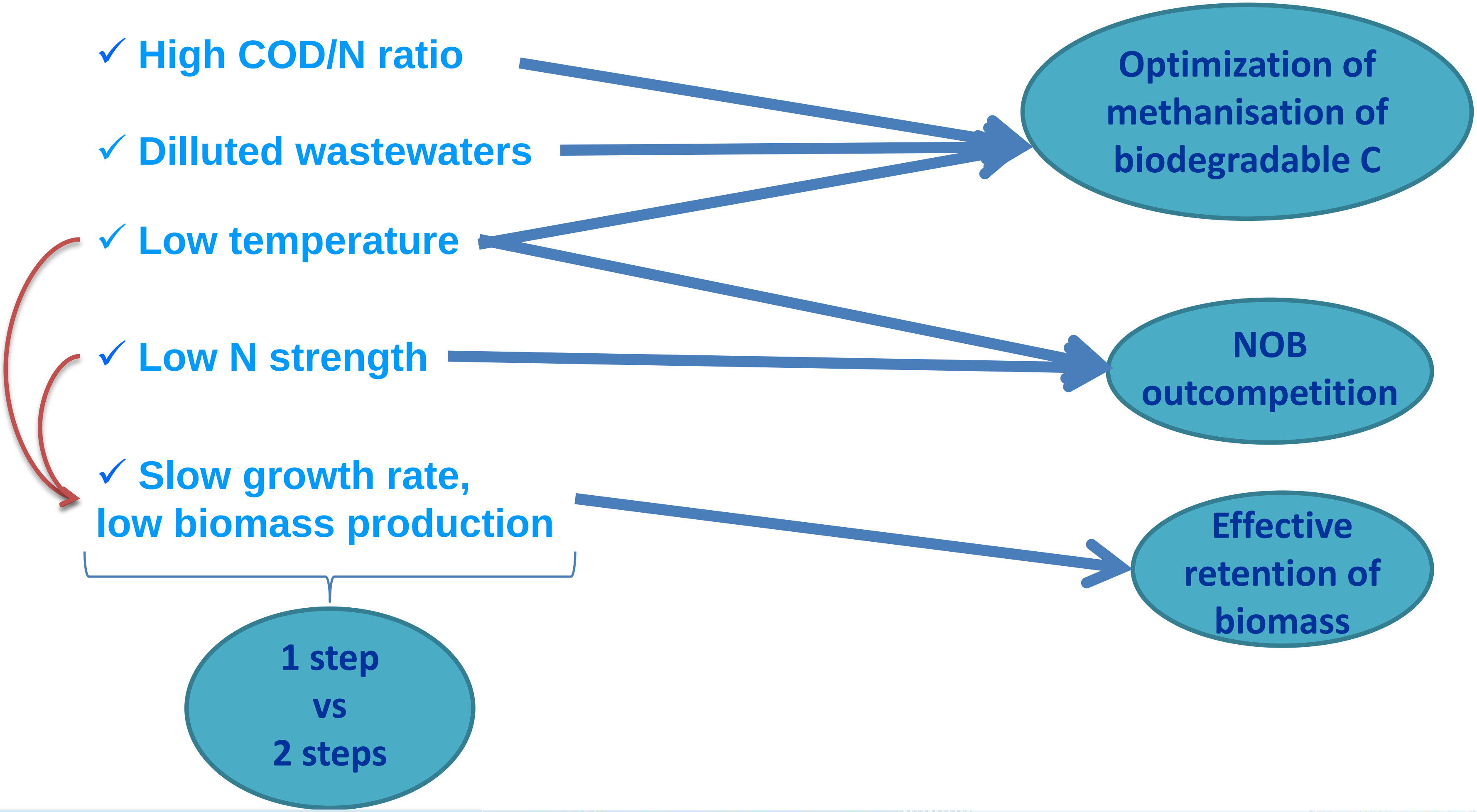
Lackner, S, Gilbert, E.M., Vlaeminck, S.E., Joss, A., Horn, H., van Loosdrecht, M.C.M.: Full-scale partial nitritation/anammox experiences—an application survey. Water Res. 55, 292–303 (2014).



- Municipal or industrial municipal-like wastewater: medium to high C/N
- Most of COD transformed into biogas: energy recovery
- Very low sludge production
- Limitations: low T, low NLR, system control and stability (NOB suppression)

Méndez R., Fernández I., Campos J.L. and Mosquera-Corral A. (2010). Aspectos Energéticos de la Tecnología Anammox. In: Ecoeficiencia en la EDAR del Siglo XXI. Aspectos ambientales y energéticos, Ed. Lápices 4, Santiago de Compostela, ISBN: 13 978 84 693 7960 8.

Anammox: improvement of start-up and operation



2. High COD/N ratio management: Strategies to maximize C energy recovery

Direct Anaerobic Digestion in the main stream

- Diluted wastewater
- Low temperature

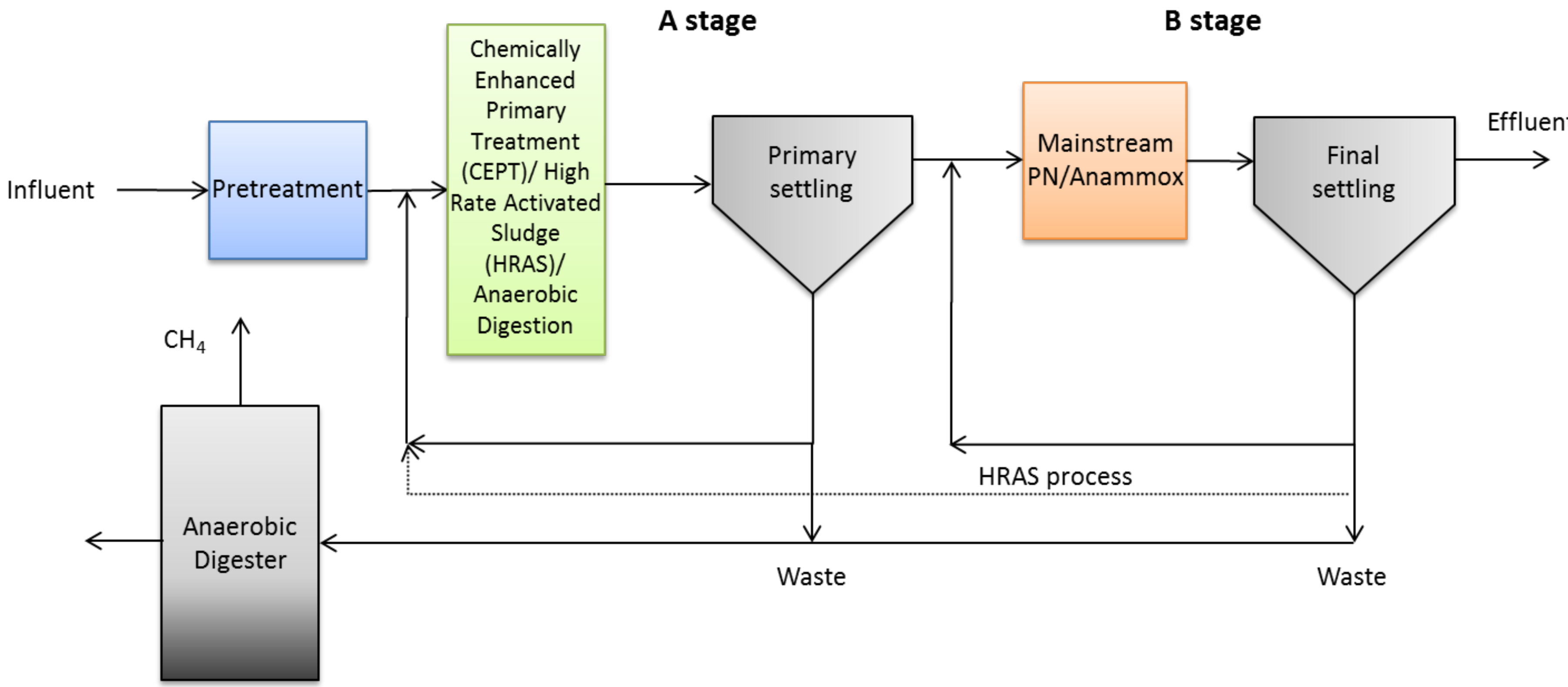
→

- Relatively low conversion (40 % at 17 ºC, Gao et al. 2014)
- Significant solubilisation of the produced CH_4 (up to 40%)

Anaerobic Co-Digestion of the main stream

Biodegradable C concentration

- Maximum recovery of particulate COD by upgraded primary settling (simplest alternative)
- Other physico-chemical treatments: sieving, dynamic sand filtration (DSF), dissolved air flotation (DAF)
- Maximum conversion of biodegradable soluble COD into biomass and recovery together with particulate COD: bioflocculation, chemically enhanced primary treatment (CEPT), high rate aerobic granulation, high rate aerobic system (HRAS)



Maximum recovery of biodegradable COD as biomass: "A-B stage" system

Xu, G., Zhou, Y., Yang, Q., Lee, Z.M.P., Gu, J., Lay, W., Cao, Y., Liu, Y.: The challenges of mainstream deammonification process for municipal used water treatment. Appl. Microbiol. Biot. 99(6), 2485-2490 (2015).

3. Low strength and low temperature wastewaters

Effective selection of AOB outcompeting NOB → **Considered the most challenging issue to be addressed for the worldwide implementation of the process**

The selection driving forces commonly implemented are not useful

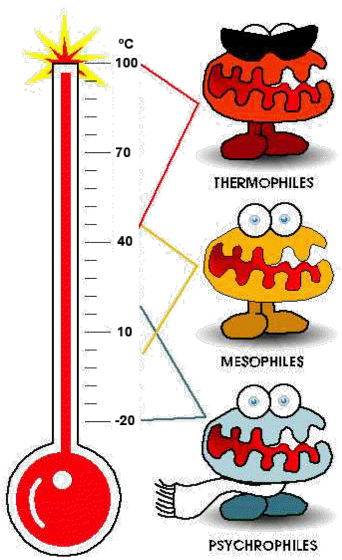
Useful tools at low strength and low T

- **Intermittent aeration → NOB are more affected by transient anoxia**
- **Use of online sensors for N species** → **NH_4^+/NO_x ratio**, **Regmi et al. 2014**, **Al Omari et al. 2015**
- **Bioaugmentation of AOB**
- **Biofilm reactors**

4. Effective retention of Anammox biomass

Anammox process:

- Y: 0.038 g VSS/g NH_4^+-N
- $t_{duplication}$ = 6-12 d (optimum)

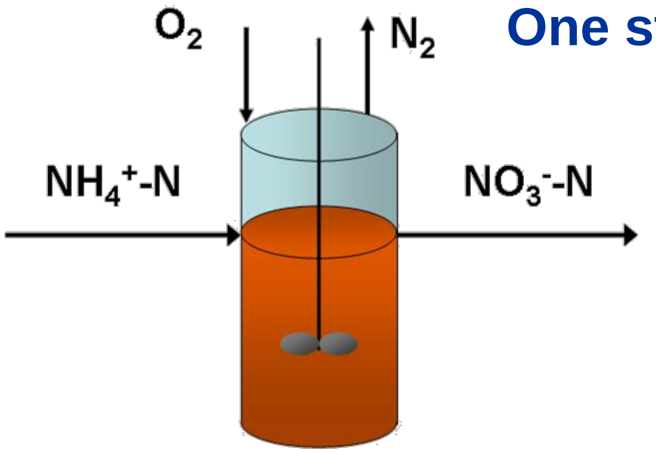


Optimum T: 35-40 ºC

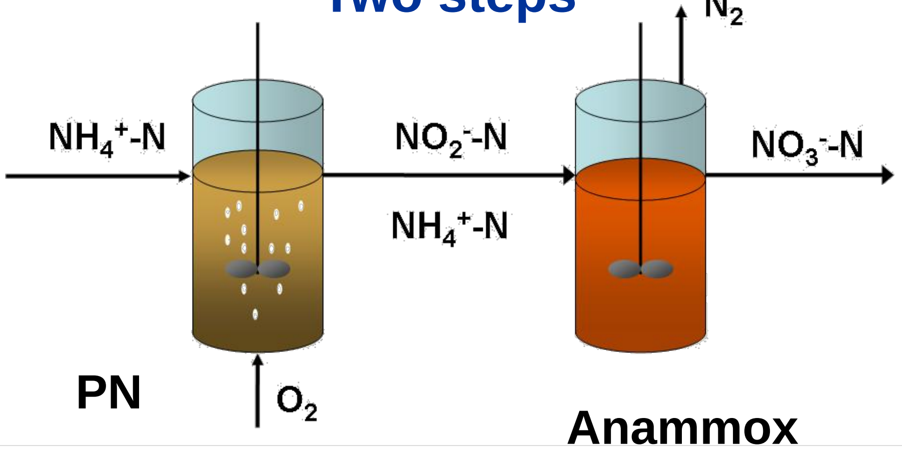
Biomass growth will be extremely slow

- Sequencing Batch Reactors (SBRs)
- Biofilm biomass (granules, biodiscs, moving bed with biofilm on support, fixed bed)
- Membrane bioreactor
- Bioaugmentation (addition of Anammox from a reactor operating near optimum conditions: ¿sidestream?)
- Concentration techniques: hydrocyclone

One step



Two steps



One step – advantages

- Lower investment costs
- More simple
- Avoids high nitrite concentrations and reduces NOx emissions

One step – drawbacks

- Affected by inhibition by remaining organics
- Variability of the influent can affect stability
- Might have lower removal rates

Two steps – advantages

- Better to avoid inhibition by remaining organic compounds
- Copes well with variability of the influent
- Easier to optimise each process

Two steps – drawbacks

- Higher investment costs
- Complexity, need for advanced control
- Possible high nitrite concentrations and NOx emissions

Significant lab scale works treating municipal-like effluents

Type of process	Aeration type	COD/N ratio	Temperature (ºC)	NRR (kg N/m^3 d)	Ref.
3 steps for AD and PN/Anammox: UAFB, PN-SBR, UFBR Anammox	Aeration time controlled PN	5 (before AD)	12-27	0.83	Gao et al. 2014
1 step: RBC	Not controlled, intermittent in space	2	14-15	0.53	De Clippeleir et al. 2013
1 step: SBR	Not controlled, continuous supply	0	12	0.02	Hu et al. 2013
2 steps: PN-CSTR, MBBR Anammox (not operated)	Intermittent, controlled by NH_4^+/NO_x ratio	6.7	25	0.15	Regmi et al. 2014
2 steps: PN (not operated), UFGSB Anammox	-	0.6-1	10-20	1.85 (20 ºC) 0.34 (10 ºC)	Lotti et al. 2014
1 step: Pilot scale plug flow granular reactor	Intermittent	0.67 (BOD/N)	19	0.16-0.19	Lotti et al. 2015

AD: Anaerobic Digestion; PN: Partial Nitritation; UAFB: Up-flow Anaerobic sludge Fixed Bed; UFBR: Up-flow Fixed-bed Biofilm Reactor; SBR: Sequencing Batch Reactor; RBC: Rotating Biological Contactor; CSTR: Continously Stirred Tank Reactor; MBBR: Moving Bed BioReactor; UFGSB: ; BOD: Biological Oxygen Demand; NRR: Nitrogen Removal Rate.

- The application of the PN/Anammox process to the main stream of the municipal and municipal-like effluents opens the possibility for the **self sufficient or energy generating WWTP**

- This highly desirable result has fueled the research towards that implementation of the PN/Anammox process

- Significant advances have been obtained to overcome the main limitations, focusing on COD removal and C energy recovery, advanced control systems, improved biomass retention and other issues

- Despite all the research effort, the application of PN/Anammox to municipal wastewater is still not a mature technology, so it will continue being a hot research topic in the future

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