NITRIFICATION-DENITRIFICATION OF RAW MUNICIPAL WASTEWATER WITHOUT RECIRCULATION, USING ENCAPSULATED MICROBIAL SYSTEMS

M. Farazaki, H. Marakas and P. Gikas

School of Environmental Engineering
Technical University of Crete
Typical wastewater treatment plant

Dominated by biological processes

Aerobic-anoxic

Anaerobic
Conventional activated sludge process with nitrification/denitrification
Energy distribution in conventional municipal wastewater treatment plant

Aprox. 12% of the energy consumption is used for primary sludge management.

Energy requirements in an issue of increased concern, as about 0.5-0.7 kWh/m³ are required for treatment.

Aprox. 60% of the energy consumption is used for aeration.

Aprox. 12% of the energy consumption is used for primary sludge management.

School of Environmental Engineering
Technical University of Crete
Microscreen - Operating principle
Microscreen

- Microscreen with open housing
- Sludge removal (~45% TS)
- Microscreen cloth (100-350μm openings)
Microscreen (Patra, Greece)
Footprint requirements

Wastewater flow: 4000 m³/d:
Microscreen footprint: 4 m²
Clarifier footprint: 82 m²
Upflow sand filters, Adelanto, California
(15000 m³/d)
Upfront solids removal (USR) process with biosolids gasification

Solids removal
- Inlet
- Microscreen
- Bar screen
- Primary filter
- BackWash flow
- B/W

Removal of dBOD & N
- Denitrification
- Trickling filter
- R
- B/W

Polishing
- Tertiary filter
- Disinfection
- Outlet

Dryer
- Biosolids

Gasifier
- Heat
- Solid residue

Syngas co-generation engine
- Electric energy

School of Environmental Engineering
Technical University of Crete
Upfront solids removal (USR) process with biosolids gasification

Inlet
Bar screen
Microscreen
Primary filter

BOD=130-160mg/L
dBOD=90-130mg/L
N-NH4+=25-50mg/L
N-NO3⁻=0-2mg/L

BOD=90-130mg/L
dBOD=90-130mg/L
N-NH4+=0-2mg/L
N-NO3⁻=25-50mg/L

BOD=90-130mg/L
dBOD=90-130mg/L
N-NH4+=25-50mg/L
N-NO3⁻=0-2mg/L

BOD=90-130mg/L
dBOD=90-130mg/L
N-NH4+=0-2mg/L
N-NO3⁻=2-5mg/L

T>μ_htr & retained autotrophs
Oxic

Air
CH₃OH

μ_heterotrophic >μ_autotrophic

BOD=240-320mg/L
dBOD=90-130mg/L
N-NH4+=25-50mg/L
N-NO3⁻=0-2mg/L

dBOD≈3.75N-NH₄⁺
Scope of work

- Investigate the performance of **encapsulated** microbial systems for nitrification/denitrification
- Examine the feasibility of “once through” nitrification/denitrification system, with no need for addition of external carbon source
- Investigate the appropriate **hydraulic retention time** for selective nitrification without BOD oxidation
- Calculate the required **reactor volume**
Biomass encapsulation process
Biomass encapsulation process
Lens shape encapsulated biomass

Inner porous matrix with entrapped microorganisms

Outer shell transmitting substrate media

Substrate media passing through the Biocatalyst

Product

200 - 400 μm

3 - 4 mm
Encapsulated biomass
Lentikats Biocatalyst – Nitrification bacteria
*Nitrosomonas europaea* and *Nitrobacter winogradskyi*
Lentikats Biocatalyst – Denitrification bacteria

*Paracoccus denitrificans* and *Pseudomonas fluorescens*
Nitrification/Denitrification dual CSTR system
Examined bioreactors

Nitrification/Denitrification bioreactors system

Stage 1: Nitrification
Stage 2: Denitrification
Stage 3: Outlet

School of Environmental Engineering
Technical University of Crete
Nitrification/Denitrification CSTR system

- Ammonium removal rates: 79% - 99%

School of Environmental Engineering
Technical University of Crete
Nitrification/Denitrification CSTR system

- Nitrate as nitrogen removal rates: 95% - 98%

![Graph showing nitrate concentration over days for different residence times (τ = 8h, 4h, 3h).]
Nitrification/Denitrification CSTR system

- BOD removal rates: 73% - 90%
Nitrification/Denitrification CSTR system

- COD removal rates: 70% - 89%

School of Environmental Engineering
Technical University of Crete
Nitrification/Denitrification CSTR system

- TOC removal rates: 70% - 89%

![Graph showing TOC concentration over days for different retention times (τ = 8h, τ = 4h, τ = 3h)]
Comparisson of encapsulated/free biocatalyst

- **Nitrification reaction rates:**
  - *Activated sludge system:* $0.21 \text{ gNH}_4^+-\text{N}_{\text{removed}}/(\text{g}_{\text{nitrifiers}} \cdot \text{d})$
  - *Encapsulated biocatalyst:* $0.23 \text{ gNH}_4^+-\text{N}_{\text{removed}}/(\text{g}_{\text{nitrifiers}} \cdot \text{d})$

- **Denitrification reaction rates:**
  - *Activated sludge system:* $0.23 \text{ gNO}_3^-\text{N}_{\text{removed}}/(\text{g}_{\text{denitrifiers}} \cdot \text{d})$
  - *Encapsulated biocatalyst:* $0.25 \text{ gNO}_3^-\text{N}_{\text{removed}}/(\text{g}_{\text{denitrifiers}} \cdot \text{d})$

Encapsulated system contained about 16 times more nitrification or denitrification microorganisms per volume, compared to activated sludge system.

At about 16 times saving space from nitrification/denitrification tanks
Conclusions

- Once through nitrification/denitrification process can be achieved using encapsulated biocatalysts

- BOD$_5$, NH$_4^+$-N and NO$_3^-$-N outlet concentrations are below the limits imposed Directive 98/15/EC, especially for the lower hydraulic retention times.

- The reactor volume for nitrification/denitrification may be reduced by 16 times, if encapsulated systems are used

- The system also saves pumping energy, while there is no need for the use of external organic carbon
Thank you for your attention!

petros.gikas@enveng.tuc.gr