Landfill leachate treatment by anammox process: CLONIC Project

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Rimini
November 7th, 2013

CLONIC project

Outline

- Background
- Project description and achievements
- Implications of the project
CLONIC project

Background

Project partners

Research group of the University of Girona (Catalonia, Spain). Working on eco-innovative water solutions since 1992.

Part of the Institute of the Environment of UdG
Teaching activity (graduate and postgraduate)
Members of TECNIO (technology transfer network)

40 members. 550 m² laboratories and pilot plants
Turnover 2012: 1,5 Millions € (35% Private – 65% Public).
Foundation of LEQUIA spin-off SISLtech S.L. www.sisltech.net in 2003
Project partners

Laboratory of chemical and environmental engineering

Our current research lines

- Design, operation and control of advanced processes for biological treatment of industrial and urban wastewaters
- Valorisation of resources within the water-energy nexus
- Environmental Decision Support Systems (EDSS)
- Advanced adsorption/oxidation processes for the treatment of liquid and gaseous effluents
Since 1999, CESPA has a specific section in the R&D department to drive initiatives in the scope of technological development (Innovation and R&D).

Cespa’s technical knowledge maintenance and continuous update in the fields related to their business activities.

Technological knowledge transfer to the different activities of CESPA
CLONIC project

Project partners

- Collection of municipal and industrial solid wastes
- Final disposal in landfills and management of landfill sites

Landfilling

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Problematic of landfill leachates

Leachates’ composition:
- Waste disposal
- Climatology
- Landfill management
- Waterproofing efficiency
- Wastes’ composition
- Waste compacting
- Age of landfill site

Background

Problematic of landfill leachates

- Mature landfill leachates
  - High ammonium content
  - OM mainly refractory COD
  - High alkalinity
  - High concentration of salts

- bCOD:N ratio < 1
- \( \text{HCO}_3^- : \text{NH}_4^+ - \text{N} = 1.14 \)
Problem definition: Nitrogen removal from leachates

Conventionally

Nitrogen removal by ammonia stripping

Refractory COD and salts removal by membrane filtration techniques

Energy consumption
pH adjustment
Gas treatment

CLONIC: looking for a new cost effective technology

R&D department of CESPA

INNOVATION SECTION:

Scope: landfill leachate treatment, research of novel solutions for current problems and investigation of new treatments for pollutants

- Interest in research on and development of biological treatments based on ANAMMOX process for ammonium removal. The anammox process offers:
  - Reduction of reagents consumption.
  - Reduction of aeration requirements by 40%.
  - Low sludge production.
CLONIC: looking for a new cost effective technology

2002 - 2007
Collaboration LEQUIA-UdG/CESPA

CLONIC project

PANAMMOX® PROCESS

Project description and achievements
Objectives

Development of a **new technology** for the **treatment of mature landfill leachates** by combining two-step **nitritation/anammox process** for full autotrophic N-removal with **thermal drying** for salts removal.

**Goals**

- Reduction of energy and reagents consumption
- Minimizing by-products and concentrated effluents production to avoid further treatment
CLONIC project

**PN-Anammox process**

- **Partial nitritation (PN):**
  - Oxidation of NH₄⁺ to NO₂⁻
  - Partial oxidation, only 57% of incoming NH₄⁺

- **Anammox (Amx):**
  - Anaerobic ammonium oxidation to N₂ gas
  - NO₂⁻ electron acceptor
  - 89% N-removed, 11% as NO₃⁻ in effluent

\[
\text{NH}_4^+ \rightarrow 1.32 \text{ NO}_2^- + 0.066 \text{ HCO}_3^- + 0.13 \text{ H}^+ \rightarrow 1.02 \text{ N}_2^- + 0.26 \text{ NO}_3^- + 0.066 \text{ CH}_4, \text{N}_2, \text{N}_0.15 + 2.03 \text{ H}_2\text{O}
\]

**Highlights:**
- Reduction of energy consumption (aeration) by 40%
- Autotrophic: no external OM required
- Capacity to treat wastewater with extremely low bCOD:TKN ratios

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CLONIC project

**Previous work**

**2002-2003: Sharon vs PN-SBR**

- Study of the SHARON process for partial nitritation (PN)
  - Partial nitritation without sludge retention (Nitrite build-up by NOB wash out)

- Starting to study the PN in **SBR technology. PN-SBR process.**
  - Effective sludge retention (Nitrite build up thanks to FA and FNA inhibition on NOB)
PN-Anammox proces (N-removal)

PN process

- Lab-scale. 20 litres reactor.
- Study of optimal operational conditions:
  - Feed-Batch vs. Step-Feed (Optimization of IC use)
  - Simulated and raw leachate treated (high N load)
- Objectives successfully reached:
  - Start-up and stable PN (1.32 NO₂⁻ : NH₄⁺)
  - Treating raw leachate with high ammonium content (3200 mg N-NH₄⁺/L)
**PN-Anammox proces (N-removal)**

**Anammox process**
- Obtaining the anammox biomass.
  - Study of different inoculum sources
- Anammox reactor start-up and enrichment:
  - Erlenmeyer (250 ml)
  - SBR (20 liters)
- Mineral medium and simulated leachate
- Objectives successfully reached:
  - Anammox biomass: *Cand. Brocadia Anammoxidans*
  - From micro- to lab-scale (scale-up to 20 liters)
  - NLR up to 1.6 Kg N·m⁻³·dia⁻¹ (92% R-removal)

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**Thermal drying**

- Pilot-plant study
  - Capacity to treat 500 kg/h of effluent
- Use of the biogas produced in landfill:
  - Biogas with a methane enrichment of 50%
- Treating real leachate in a landfill of CORSA
- Objectives successfully reached:
  - All pollutants immobilized in the dry powder
  - Atmospheric emissions and effluent under the discharge limits
  - Dry powder appropriate for landfill disposal
Results of CLONIC

New treatment configuration successfully tested, showing good N and salts removal efficiencies.

Environmental cost of the treatment:
- 25.66 €/m³ by conventional treatment
- 13.32 €/m³ by CLONIC configuration

Results of CLONIC

PANAMMOX® process

Two-step PN-Anammox process
Implications of the project

- Development and implementation of the PANAMMOX® technology

After the positive results obtained during CLONIC project, CESPA and LEQUIA decided to proceed with the development of the PANAMMOX® process in view to final industrial implementation in CESPA's landfill sites as a cost-effective alternative to current leachate treatments.
Implications of the project

- **Development and implementation of the PANAMMOX® technology**

  - **SCALE-UP**
    - Lab-scale (10-20 L)
    - Pilot-scale (20-250 L)
    - Semi-Industrial (400 L)

  - **2012: Process implemented at semi-industrial scale, in-situ and treating different influents**

  - **Influent**
    - Landfill leachate
    - Digestion returns in WWTP

  - **Semi-industrial pilot plants**
    - Reactor volume
      - 400L
      - 250L
      - 400L

  - **Study of biological processes: PN+Anammox**
  - **Anammox biomass enrichment and process control**
  - **Adaptation to raw leachate (anammox)**
  - **Extreme conditions**
  - **Pre-industrial scale treating real leachate.**
  - **Pre-industrial scale application to sludge digestion returns in WWTP.**

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N-OPTIMOX project (2013-2014): Final step to industrial implementation

N-OPTIMOX

Construction of the first PANAMMOX demonstration full-scale plant in a landfill site to remove nitrogen from landfill leachate.

- Start date of civil work: November 2013
- Plant in operation: end 2014

Leachate characteristics:

<table>
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<th>Parameter</th>
<th>Units</th>
<th>Mean</th>
<th>δ</th>
<th>Min.</th>
<th>Max</th>
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<tr>
<td>Conductivity</td>
<td>mS/cm</td>
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<td>8.54</td>
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<tr>
<td>Ammonium nitrogen</td>
<td>mgN/L</td>
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<td>816</td>
<td>635</td>
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<td>COD</td>
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<td>Chlorides</td>
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<td>8.4</td>
<td>0.4</td>
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</tr>
</tbody>
</table>

Daily flow to treat: 19 m³
**CLONIC project**

**Implications of the project**

- **N-OPTIMOX project (2013-2014): Final step to industrial implementation**

**CORSA**

Current treatment:
1. Phenton (COD removal)
2. Stripping (N removal)

**Implementation of PANAMMOX® in CORSA**
**N-OPTIMOX project (2013-2014): Final step to industrial implementation**

**Implementation of PANAMMOX® in CORSA**

![Diagram of PHENTON PROCESS with reactors and treatment steps](image)

**Cost Savings with PANAMMOX® in CORSA**

- **Current Treatment Cost**: 46.5 €/m³
- **PANAMMOX Treatment Cost**: 29.3 €/m³
- **Reagents cost reduced by 54%**
  - Better use of alkalinity (H₂SO₄)
  - bCOD biologically removed (H₂O₂)
- **Effluents management cost reduced by 22%**
  - No (NH₄)₂SO₄ produced
  - Less effluent volume (lower dosage)

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**CLONIC project**

- **N-OPTIMOX project (2013-2014): Final step to industrial implementation**

**Current technology development**

- Effluent quality required
- N-removal PANAMMOX®
- Other pollutants Second step
- Ultrafiltration
- Thermal drying
- AOP (Photo-Fenton)
- others...

Different process configurations by coupling the PANAMMOX® process with other technologies to offer the best treatment in each case.

**Summary of 11-year collaboration CESPA-LEQUIA**

Development and implementation of PANAMMOX technology

Research carried out in LEQUIA has provided scientific and technical knowledge that CESPA can implement to supply its business necessities.

- **The private company: CESPA**
  - Need for new alternatives for wastewater treatment
  - Willingness to support researchers and find financial aids for research activities
  - Agreement of funding research activities
- **University of Girona: LEQUIA**
  - Research to develop scientific-technical knowledge and technology transfer
  - Training activity (3 PhD defended) and publications in high impact journals (14)
  - Experience in identifying real needs to define research projects
CLONIC project

Acknowledgements

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LEAMMOX. CIT-310000-2009-063).

NIMOX. (IAP-560620-2008-59).


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