Evaluation of electrode surface treatments in sludge electro-osmosis dewatering

P. Gronchi, R. Canziani, A. Brenna, S. Visigalli, C. Colominas, F. Montalà, V. Cot, A. Stradi, G. Ferrari, V. Bellelli, C. Diaz, G. Garcia Fuentes
AIMS OF THE STUDY

- Investigation of sludge electro-dewatering efficiency ($DS_f$ and total energy consumption).
- Comparison between static and dynamic tests.
- Choice of suitable anodes in terms of corrosion resistance.

Stradi et al. patent device (WO 2011/161568 A1)
OBJECTIVES OF SLUDGE DEWATERING

- Recovery of the sludge for sale in a dry form (direct land application in agriculture, composting or incineration).
- Transformation of the waste into forms that are easily handled and can be safely disposed of, with a reduction in transport costs.
- Recovery of water for recycling.

MECHANICAL DEWATERING

- Plate filter press
- Belt filter press
- Vacuum filtration
- Centrifuge

ELECTRO-DEWATERING

DS≈25%

DS≈40-45%
ELECTRO-OSMOSIS DEWATERING OF SLUDGE

- Electrophoresis
- Electro-osmosis
- Electromigration
- Electrochemical reactions

![Diagram of dewatering process with labels for each step: Initial suspended solids, Mechanical dewatering, Electro-Dewatering, Electrophoresis, Electro-osmosis, Electromigration. Equations for electrochemical reactions are also shown: $2H_2O \rightarrow 4H^+ + O_{2(g)} + 4e^-$ for $[H^+]$ increase, pH decrease; $2H_2O + 2e^- \rightarrow H_2(g) + 2OH^-$ for $[H^+]$ decrease, pH increase.]}
DEVICE ASSEMBLING

- Cylindrical glass vessel (h=176 mm, Ø=80 mm)
- Cooling water-jacket
- Compressed air system (1-4.5 bar)
- Double effect cylinder (200 mm stroke) SMC-CP96
- DC power supply (30 V-5 A)
- Anode: DSA, stainless steel or PVD coated SS
- Cathode: stainless steel mesh (AISI 304)
- Cloth: PTT (polytrimethyleneterephthalate)

STATIC PISTON

ROTATING PISTON
EXPERIMENTAL OPERATIONS

Two successive stages:
- filtration/compression by applying pressure ($P=3$ bar - $t_p=5$ min).
- application of an electric field at the selected operating voltage, keeping the applied pressure constant.

ANODES IN ELECTRO-DEWATERING

**DSA - Ti(MMO):**
- High corrosion resistance.
- Expensive.

**Stainless steel (AISI 304):**
- Best quality/price ratio.
- Low corrosion resistance.

**PVD coated stainless steel (TiN, AlTiN, DLC):**
- High hardness, wear and abrasion resistance.
- Low conductivity.
ELECTRO-DEWATERING EFFICIENCY - DSA

Good efficiency in terms of $DS_f$ and energy consumptions at 10-15 V/cm

$DS_f = 20.1\%$

$Th = 1\ cm$

<table>
<thead>
<tr>
<th>$N^0$</th>
<th>$E$ [V/cm]</th>
<th>$t_{tot}$ [min]</th>
<th>Specific energy consumption [Wh/kg$_{H2O}$]</th>
<th>$DS_f$ [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM-1</td>
<td>10</td>
<td>65-105</td>
<td>168.7</td>
<td>38.9</td>
</tr>
<tr>
<td>AM-2</td>
<td>15</td>
<td>55-61</td>
<td>266.3</td>
<td>39.9</td>
</tr>
<tr>
<td>AM-3</td>
<td>20</td>
<td>45-52</td>
<td>343.9</td>
<td>40.5</td>
</tr>
</tbody>
</table>
ELECTRO-DEWATERING EFFICIENCY – Stainless steel

High potential values are needed to increase DS amount.

$DS_i=23.6\%$

$Th=1\ cm$

<table>
<thead>
<tr>
<th>$N^o$</th>
<th>$E$ [V/cm]</th>
<th>$t_{tot}$ [min]</th>
<th>Specific energy consumption [Wh/kg$_{H_2O}$]</th>
<th>$DS_f$ [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>FM-1</td>
<td>10</td>
<td>30-35</td>
<td>495.4</td>
<td>27.1</td>
</tr>
<tr>
<td>FM-2</td>
<td>15</td>
<td>22-25</td>
<td>428.8</td>
<td>29.4</td>
</tr>
<tr>
<td>FM-3</td>
<td>20</td>
<td>18-23</td>
<td>287.6</td>
<td>37.1</td>
</tr>
</tbody>
</table>
ELECTRO-DEWATERING EFFICIENCY – TiN

A higher efficiency is achieved with a protective coating, thanks to a lower corrosion in the first minutes. Higher the coating thickness, lower the conductivity of the anode.

\[ DS_f = 23.6\% \]

\[ Th = 1 \text{ cm} \]

<table>
<thead>
<tr>
<th>N°</th>
<th>E [V/cm]</th>
<th>( t_{\text{tot}} ) [min]</th>
<th>Specific energy consumption [Wh/kg( \text{H}_2\text{O} )]</th>
<th>DS( f )[%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-10 (1 ( \mu \text{m} ))</td>
<td>15</td>
<td>17</td>
<td>119.2</td>
<td>39.7</td>
</tr>
<tr>
<td>F-11 (3 ( \mu \text{m} ))</td>
<td>15</td>
<td>18</td>
<td>136.9</td>
<td>38.8</td>
</tr>
</tbody>
</table>
ELECTRO-DEWATERING EFFICIENCY – AlTiN and DLC

$DS_i = 21.9\%$

$Th = 3\, \text{cm}$

<table>
<thead>
<tr>
<th>N°</th>
<th>E [V/cm]</th>
<th>$t_{\text{tot}}$ [min]</th>
<th>Specific energy consumption [Wh/kg$_{\text{H}_2\text{O}}$]</th>
<th>$DS_i$ [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>G-1 (static)</td>
<td>15</td>
<td>30</td>
<td>385.1</td>
<td>25.7</td>
</tr>
<tr>
<td>G-2 (rotating)</td>
<td>15</td>
<td>30</td>
<td>277.3</td>
<td>28.0</td>
</tr>
<tr>
<td>G-3 (rotating)</td>
<td>15</td>
<td>30</td>
<td>253.9</td>
<td>28.3</td>
</tr>
<tr>
<td>G-4 (rotating)</td>
<td>15</td>
<td>30</td>
<td>296.0</td>
<td>27.5</td>
</tr>
</tbody>
</table>
CORROSION

**DSA**

**Stainless steel**

[Images of corrosion samples]
CORROSION

$Ti\text{N}$ coating

$AlTi\text{N}$ coating

$DLC$ coating
CONCLUSIONS

- The main parameters which control electro-osmosis process are sludge cake thickness, potential value, $D_s$, and material of the electrodes.
- With potential values of 10 V, 15 V and 20 V, a $D_s$ amount has been found around 37-41%, if a dimensionally stable anode is used.
- Dewatering rate increases with electric field.
- Rotation of the anode increases the conductivity of the sludge thanks to a mixing of the cake.
- DSAs are the best materials to be used in electro-osmosis due to their high corrosion resistance.
FUTURE WORK

Lab-scale critical points:

– Only low cake thicknesses (1-1.5 cm) can be treated.
– Increase of resistance of sludge with the proceeding of dewatering.
– Continuous feed of sludge is not possible.
– Production of gases and possibility of explosions due to electrochemical reactions.
– Low efficiency and high energy consumption for dry sludge ($DS_i > 25\%$).
FUTURE WORK

Lab-scale critical points:

– Only low cake thicknesses (1-1.5 cm) can be treated.
– Increase of resistance of sludge with the proceeding of dewatering.
– Continuous feed of sludge is not possible.
– Production of gases and possibility of explosions due to electrochemical reactions.
– Low efficiency and high energy consumption for dry sludge (DSi>25%).

Stradi et al. patented device
FUTURE WORK

Choice of the anode:

– DSA is a corrosion resistant anode but results to be too expensive.
– Stainless steel is cheaper but it is corroded easily.
– PVD coatings increases wear resistance but are subject to corrosion and lower the conductivity of the anode.
**FUTURE WORK**

*Choice of the anode:*

- DSA is a corrosion resistant anode but results to be too expensive.
- Stainless steel is cheaper but it is corroded easily.
- PVD coatings increases wear resistance but are subject to corrosion and lower the conductivity of the anode.

---

**Polymeric coating with a dispersion of graphene or carbon nanotubes:**

- Increase of conductivity
- Increase of corrosion resistance

---

**Project FP7 «SLUDGETREAT»**


**Project LIFE14 «ELECTRO-SLUDGE»**

- 1/9/2015 – 31/12/2018 – Stradi et al. patented prototype tests.
Thank you for your kind attention!
The LIFE14 project no. ENV/IT/000039 “ELECTRO-SLUDGE” has been partly funded with the contribution of the LIFE Programme of the European Union http://www.electrosludge.eu/

Sludgetreat Project no. 611593 co-funded by the European Commission within FP7 (2007–2013)
Marie Curie Actions—Industry-Academia Partnerships and Pathways (IAPP)
http://cordis.europa.eu/project/rcn/191799_it.html

Partners:
- AST – coordinator
- Politecnico di Milano
- CAP Holding S.p.A.

Partners:
- AST – coordinator
- Politecnico di Milano
- Flubetech (Barcelona)
- AIN (Pamplona)
CORROSION

STAINLESS STEEL:
- High acidity and passive film breakdown at 10 A/m²
- High overvoltage

DSA:
- No modification in the passive film during trans-passivity
- Low overvoltage: MMO works as catalysts for reactions