HERAKLION 2019

International Conference on Sustainable Solid Waste Management
26 – 29 June 2019

Application of semi-continuous pilot-scale AD tests to assess biochemical methane potential and hydrolysis rate constant of raw and pre-treated sludge

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http://www.wearwe.polito.it

Castiglione Torinese WWTP

Municipal and industrial wastewater

Capacity: 2,000,000 E.I.

Average flow rate: 7 m³/s

Pre-treatments

Pretreatment / Feedstock	Mechanical	Thermal	Chemical	Biological
Sludge	Sonication High pressure Lysing centrifude Focused pulsed technique	Steam explosion Hydrothermal		

Low thermal, alkali and low temperature thermo-alkali pretreatments

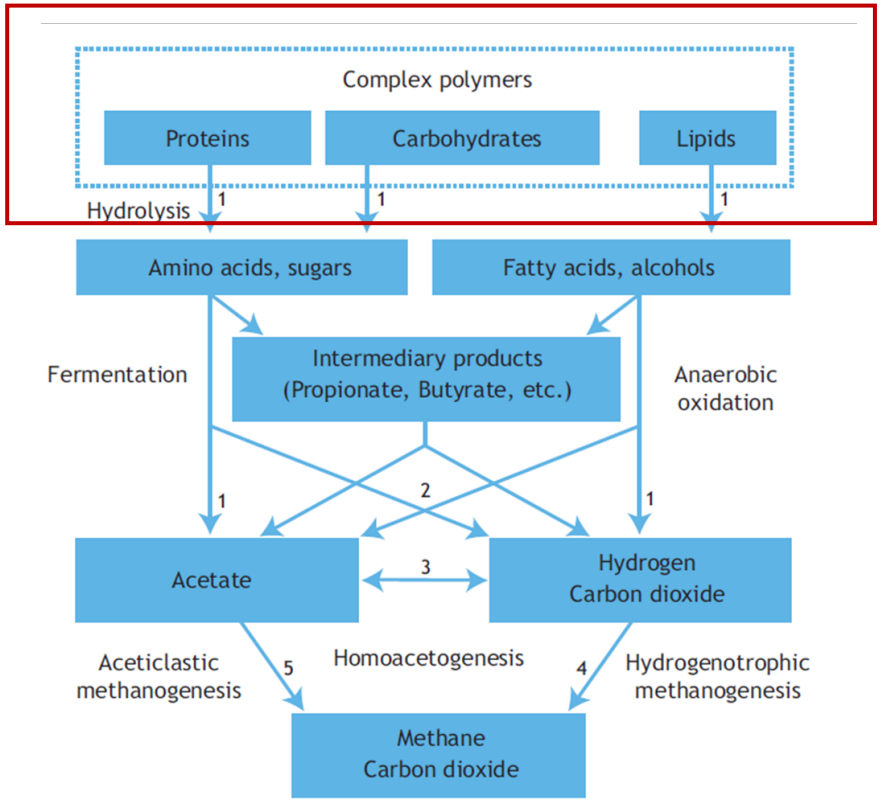
Polito-Smat

Low temperature thermo – alkali pre-treatment

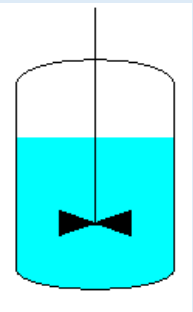
4kg NaOH /100kg TS, 90 °C, 1.5h

"Review of feedstock pretreatment strategies for improved anaerobic digestion: From lab-scale research to full-scale application"

Carrere H., Antonopoulou G., Affes R., Passos, Battimelli A., Lyberatos G,Ferrer I. (2016) Review of feedstock pretreatment strategies for improved anaerobic digestion: From lab-scale research to full-scale application Bioresour. Technol.Vol. 199, 386–397

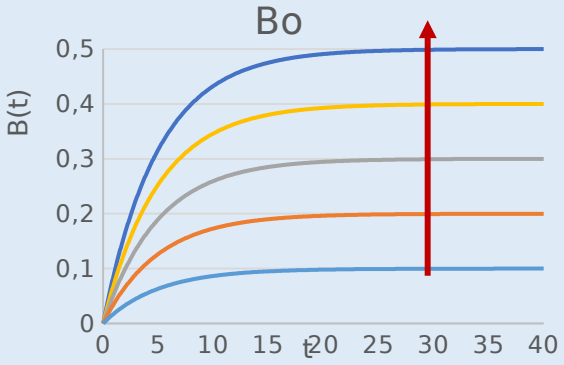


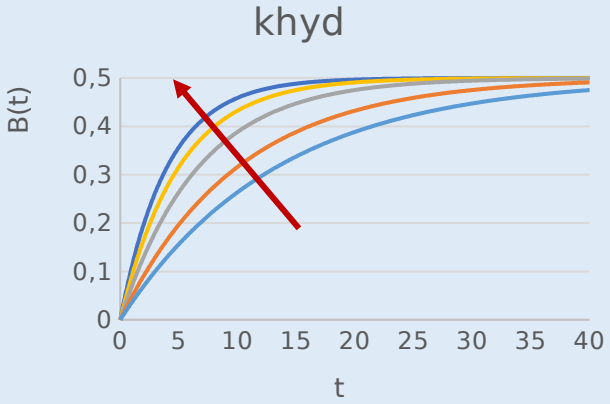
Batch Reactor



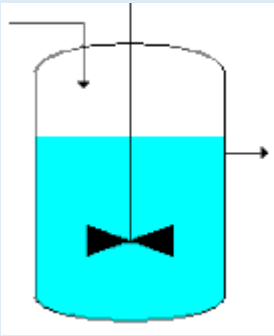
$$\frac{dS}{dt} = -k\,S_0 \qquad S = S_o e^{-k\,t}$$

$$B = \left(1 - e^{-k\,t}\right) B_o$$





CST Reactor

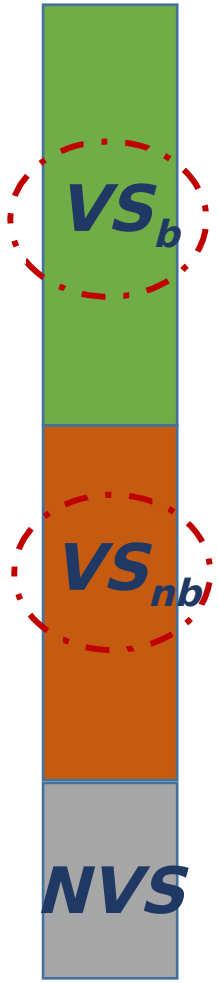


$$\frac{dS}{dt} = \frac{qS_0}{V} - \frac{qS}{V} - kS$$

$$S = \frac{1}{1 + k\,HRT} S_o$$

$$B = \left(1 - \frac{1}{1 + k\,HRT}\right) B_o$$

CSTR Digester



$$\frac{dVS_b(t)}{dt} = \frac{q(t) \times VS_{b_{\text{in}}}(t)}{V} - \frac{q(t) \times VS_b(t)}{V} - k \times VS_b(t)$$

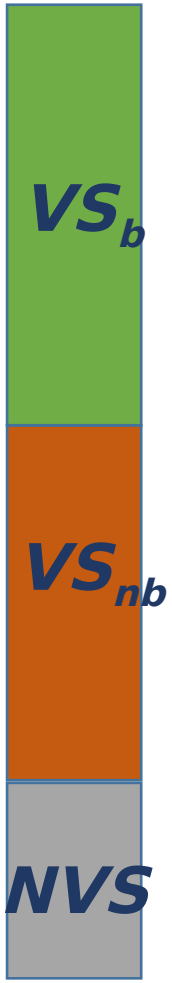
$$B_{CH_4}(t) = VS_b(t) \times k \times B_{\text{th}} \times V$$

?

$$\frac{dVS_{nb}(t)}{dt} = \frac{q(t) \times VS_{nb_{\text{in}}}(t)}{V} - \frac{q(t) \times VS_{nb}(t)}{V}$$

$$\frac{dNVS(t)}{dt} = \frac{q(t) \times NVS_{\text{in}}(t)}{V} - \frac{q(t) \times NVS(t)}{V}$$

CSTR Digester



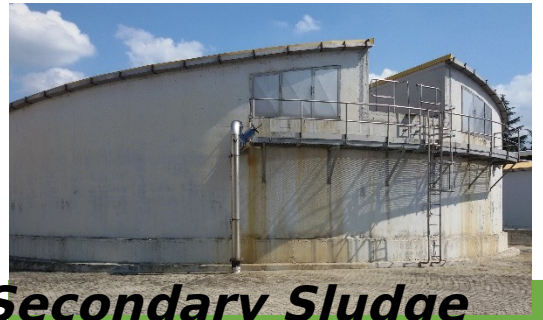
$$\frac{dVS_b(t)}{dt} = \frac{q(t) \times Vs_{b_{\text{in}}}(t)}{V} - \frac{q(t) \times VS_b(t)}{V} - k \times VS_b(t)$$

$$\frac{daVS(t)}{dt} = \frac{q(t) \times VS_{in}(t)}{V} - \frac{q(t) \times aVS(t)}{V} - \mathrm{k} \times aVS(t)$$

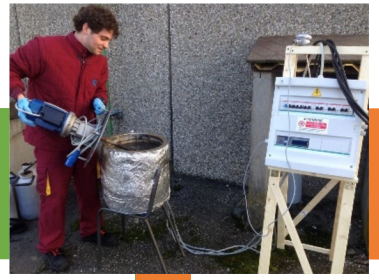
$$B_{CH_4}(t) = VS_b(t) \times k \times B_{\text{th}} \times V$$

$$B_d(t) = aVS_b(t) \times k \times B_o \times V$$

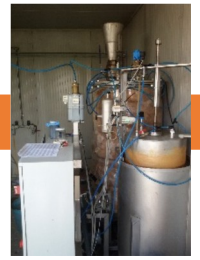
Pilot Anaerobic digestion tests



Secondary Sludge

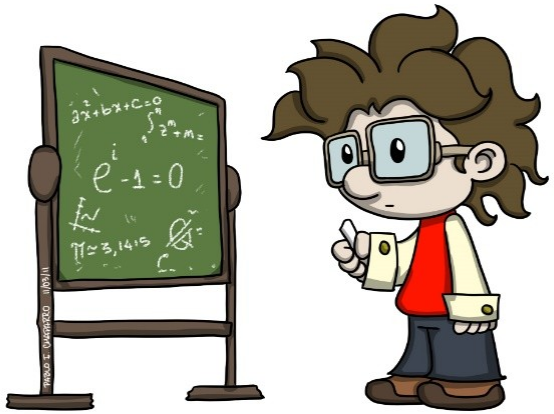


Mesophilic Anaerobic Digestion (38°C)

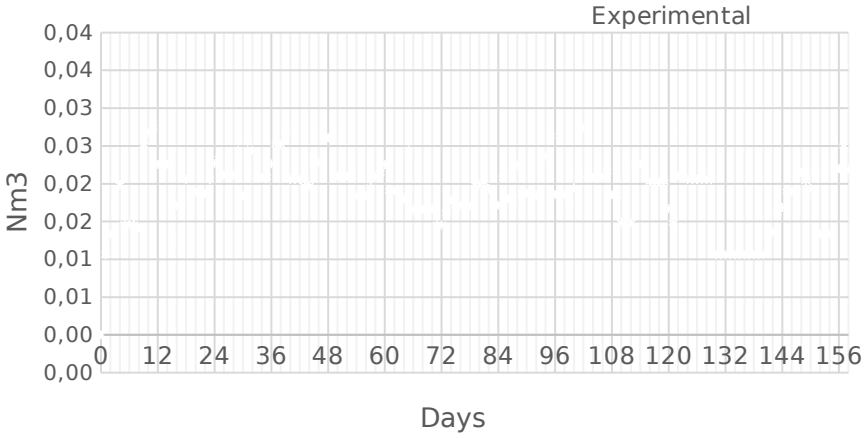


Primary Sludge

$$\frac{daVS(t)}{dt} = \frac{q(t) \times VS_{in}\,(t)}{V} - \frac{q(t) \times aVS(t)}{V} - k \times aVS(t)$$



$$B_d(t) = aVS(t) \times k \times B_o \times V \qquad C_{CH_4} = \int_0^t B_d(t)dt$$



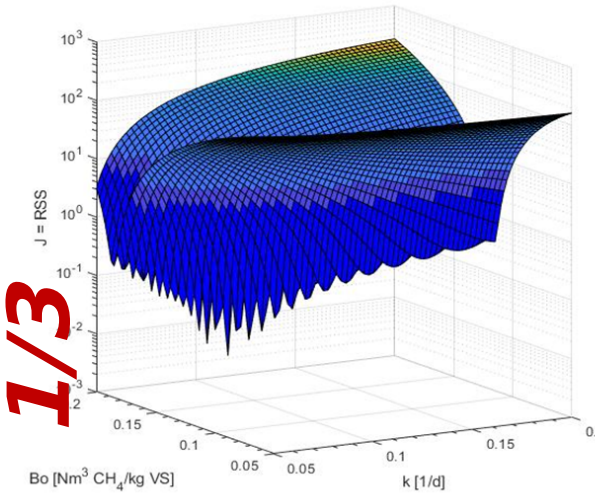
$$B_{exp_{CH_4}} = \lfloor B_{exp_{t(1)}}; B_{exp_{t(2)}}; B_{exp_{t(3)}}; \ldots\ldots\ldots B_{exp_{t\,end}} \rfloor$$

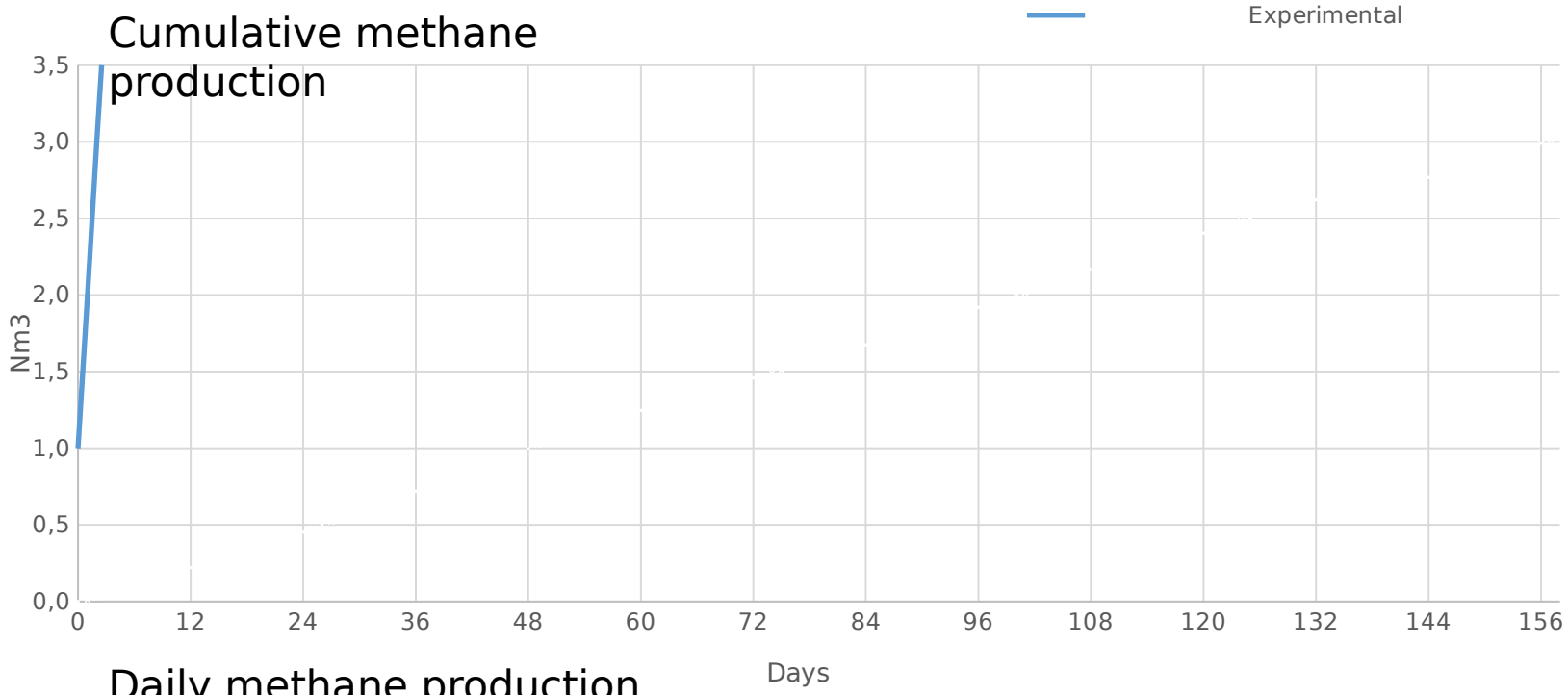
$$C_{exp_{CH_4}} = \sum_{t(1)}^{t(i)} B_{exp_{CH_4}}$$

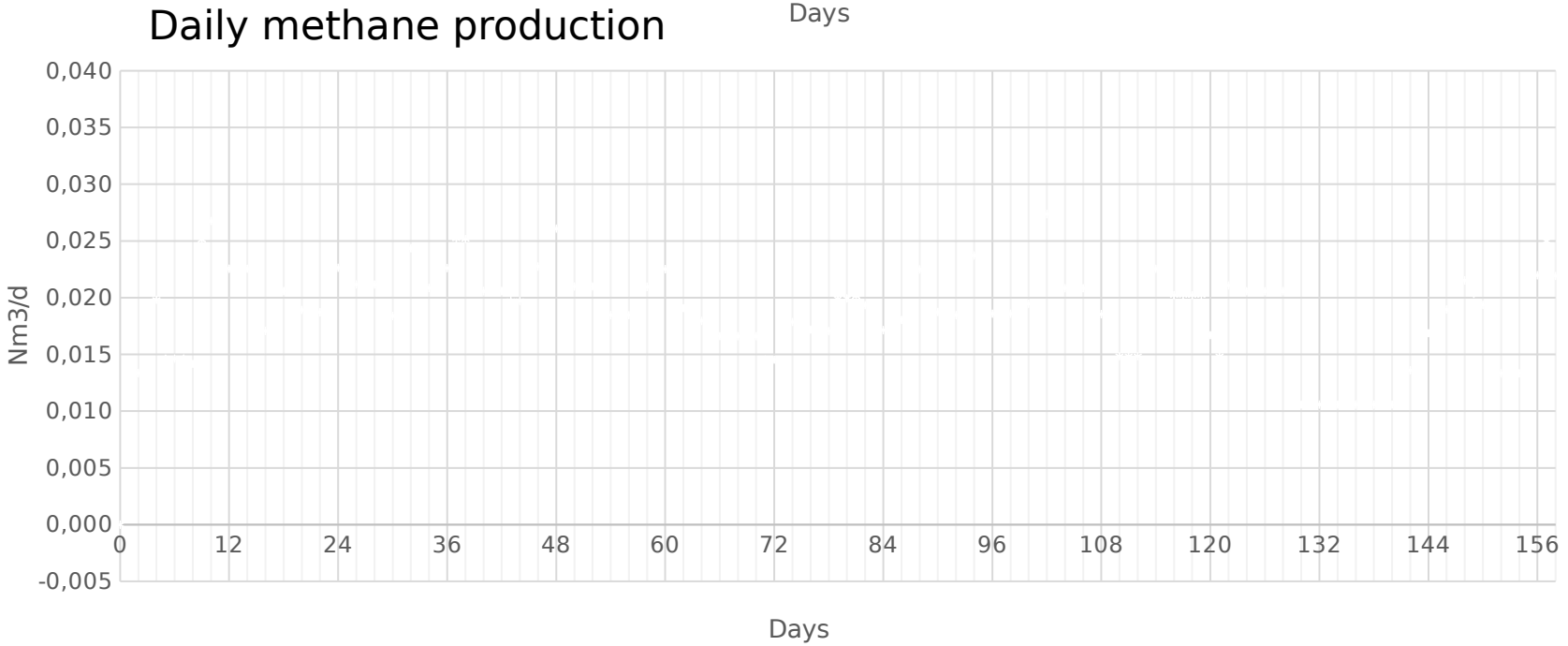
$$\boldsymbol{M_{S\_RSS}(i,j) = \sum_{t=1}^{t=t_{end}} \left(C_{exp_{CH_4}}(t) - C_{CH_4}(t) \right)^2}$$

$$\boldsymbol{J_{min} = min\_M_{S\_RSS}(i,j)}$$

Calibration 1/3

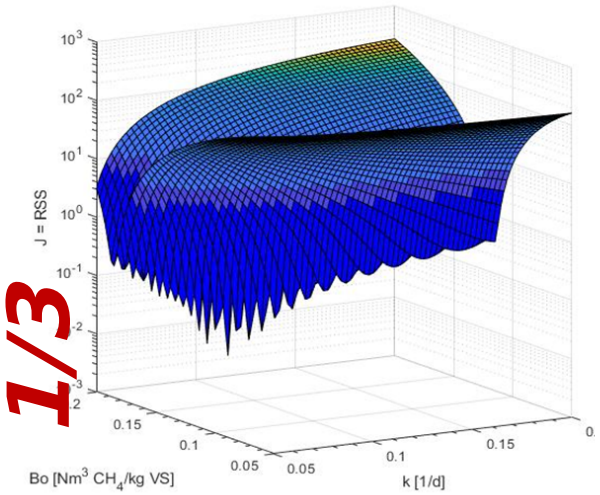


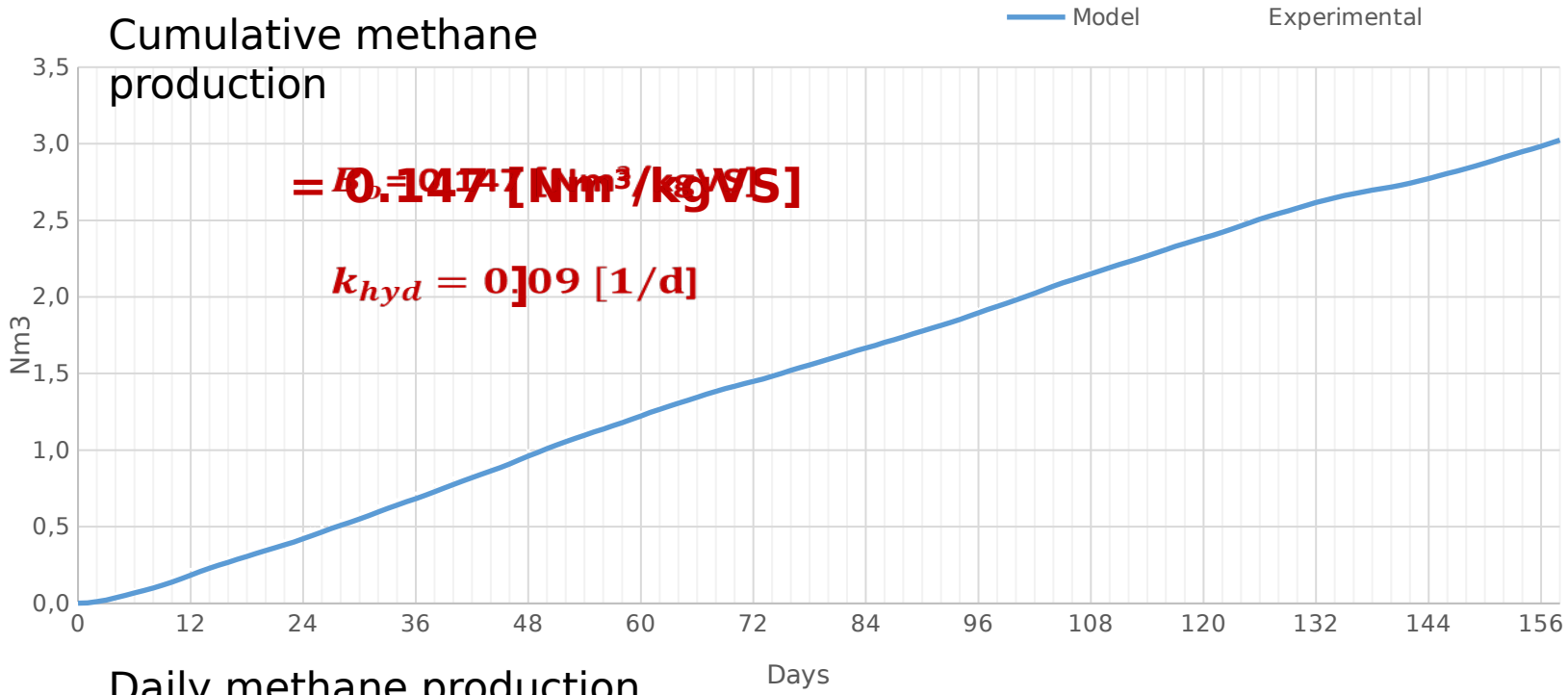


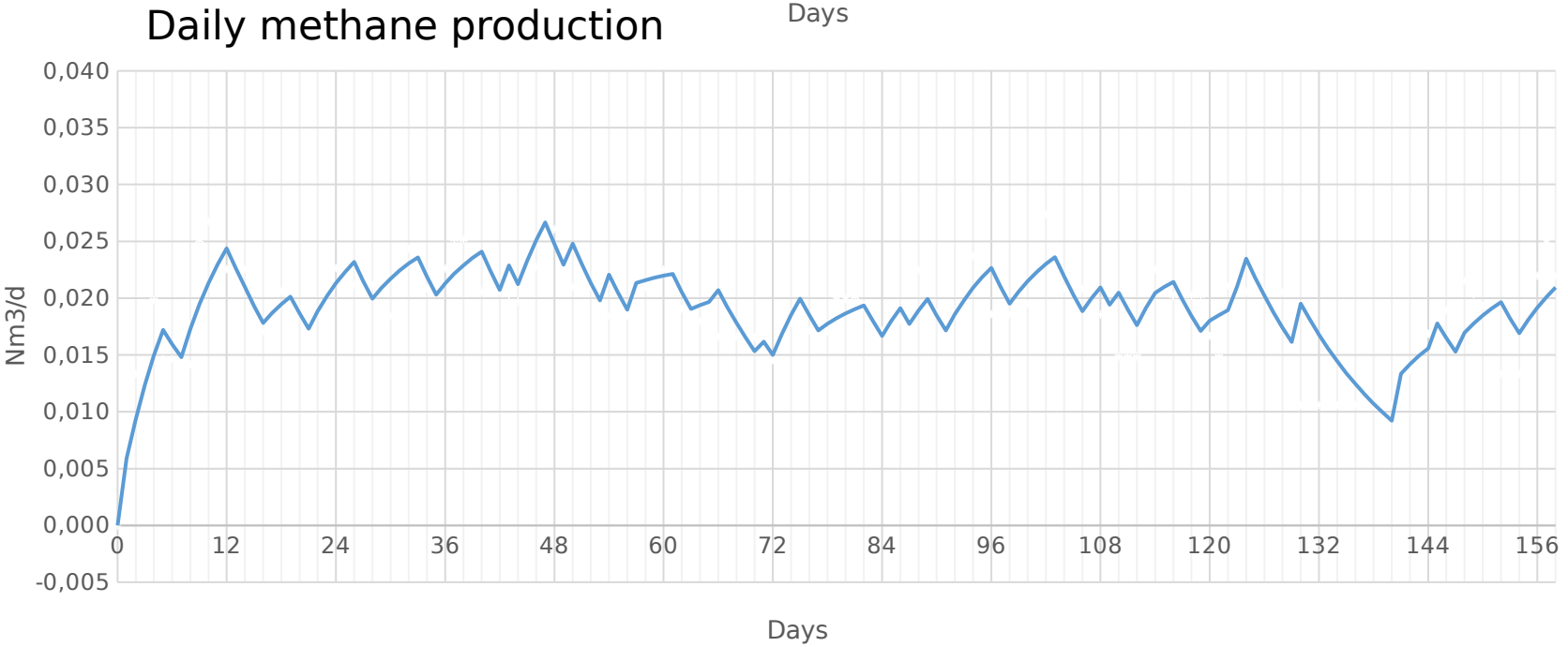


Secondary Sludge

Calibration 1/3



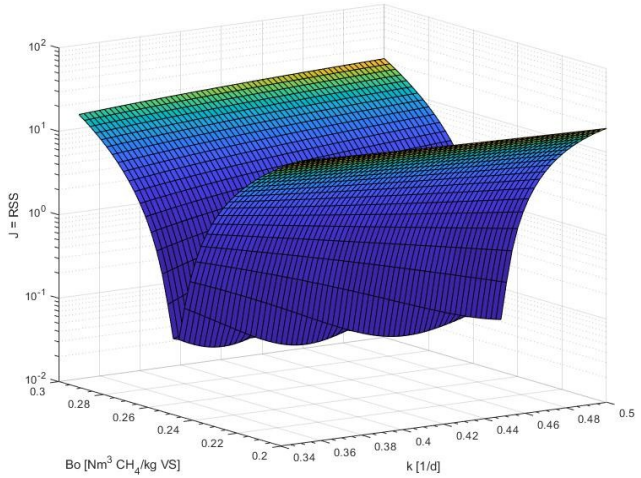


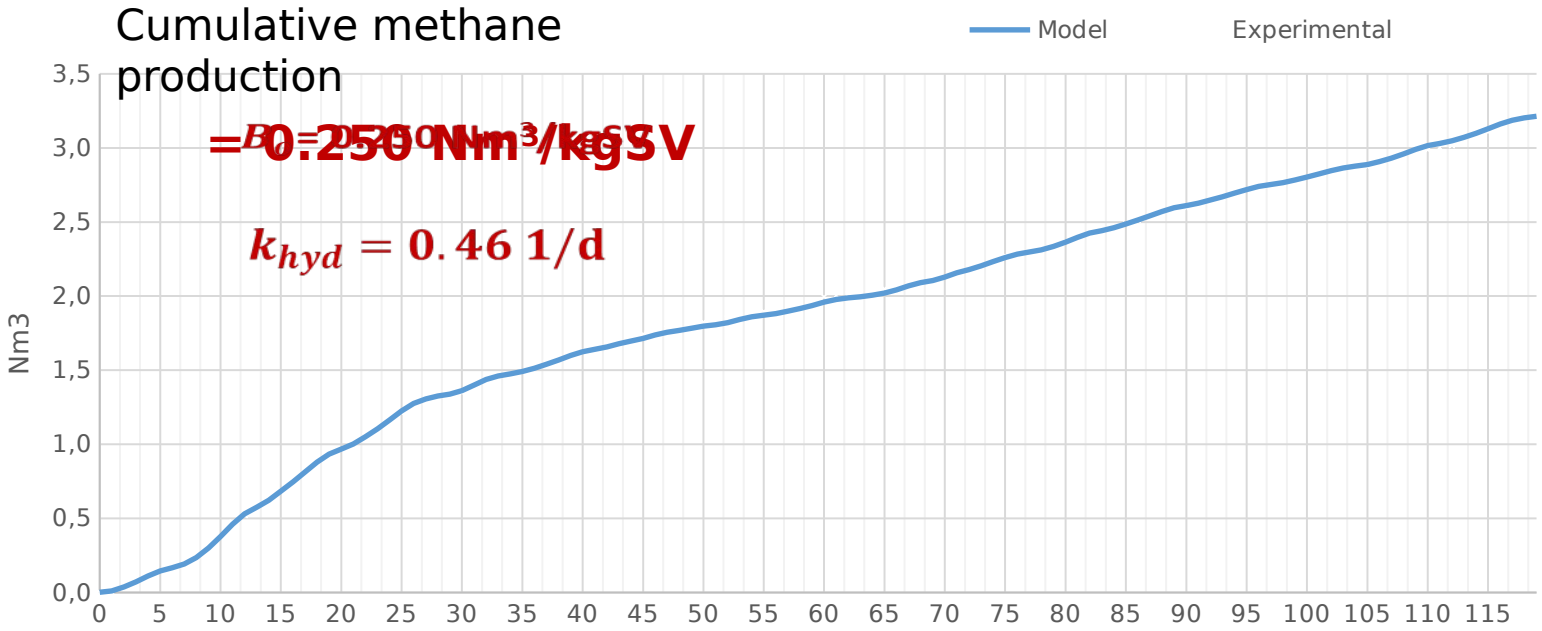


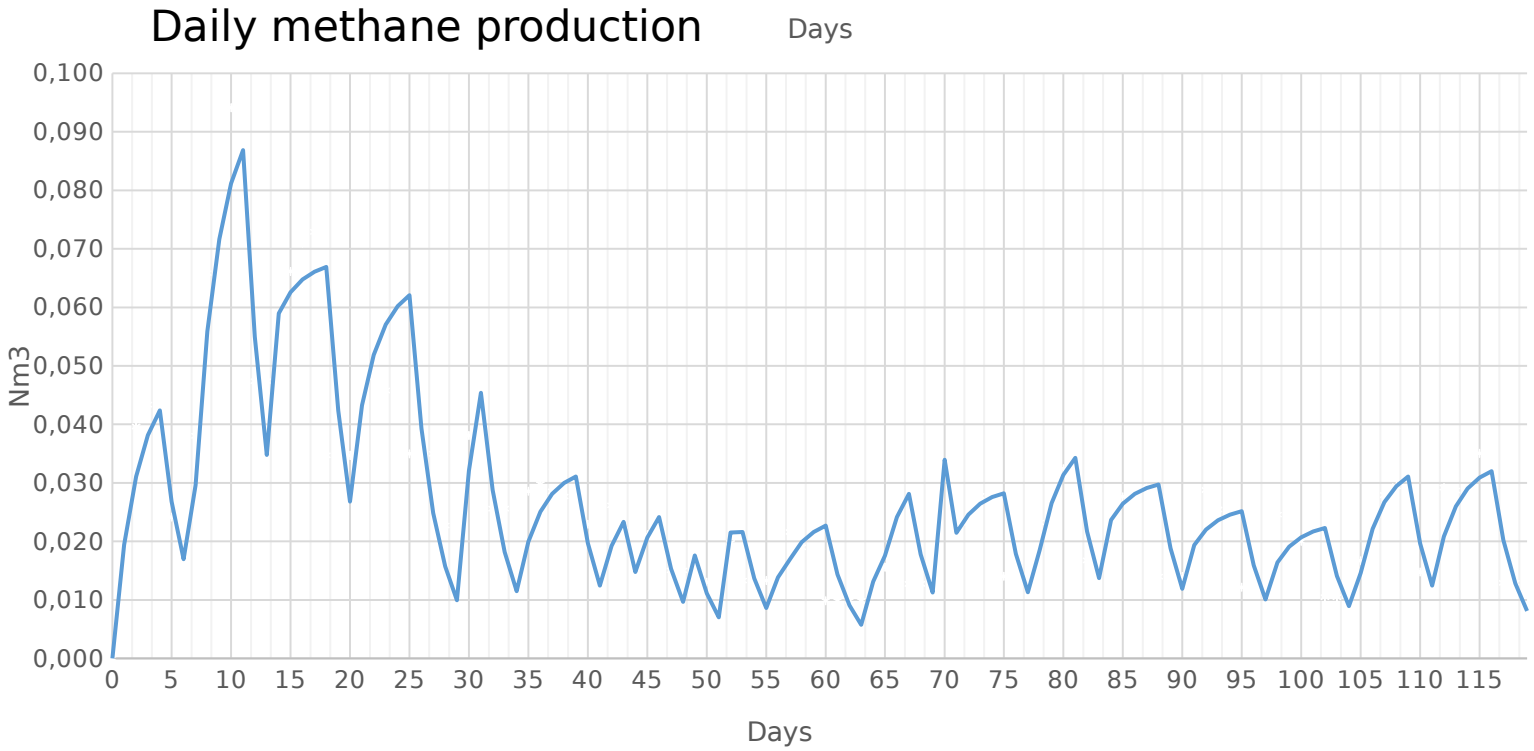
Secondary Sludge

Pre-treatment: 90 °C - 1,5 h – 4g NaOH/100gST

Calibration



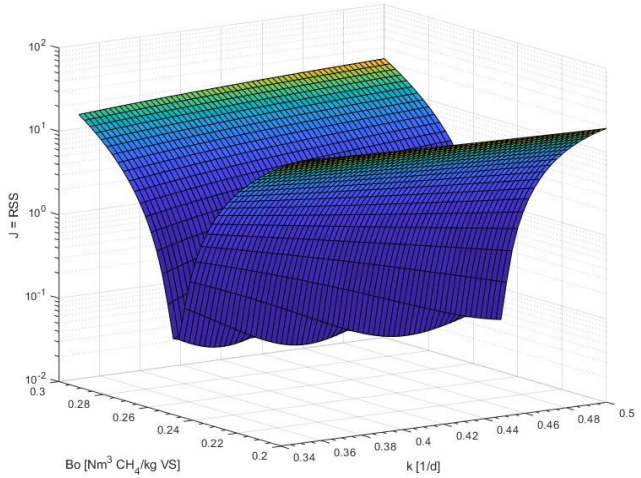


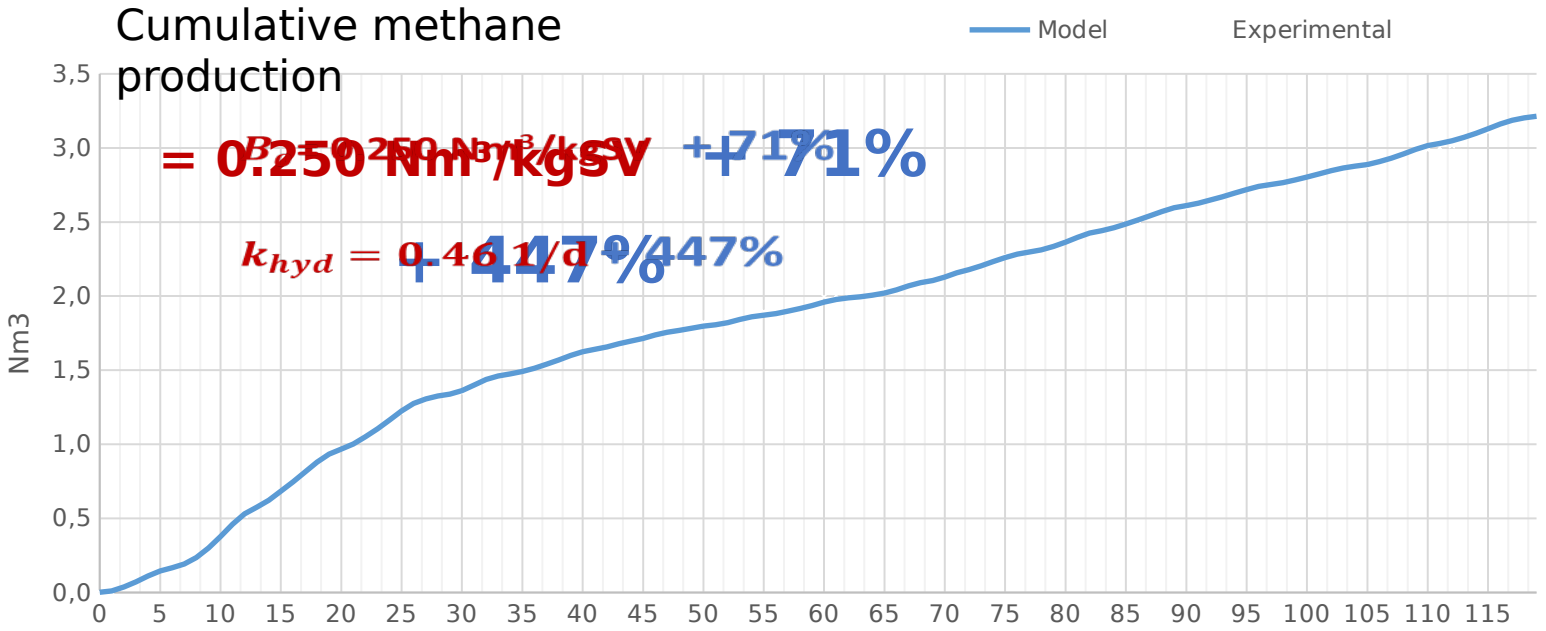


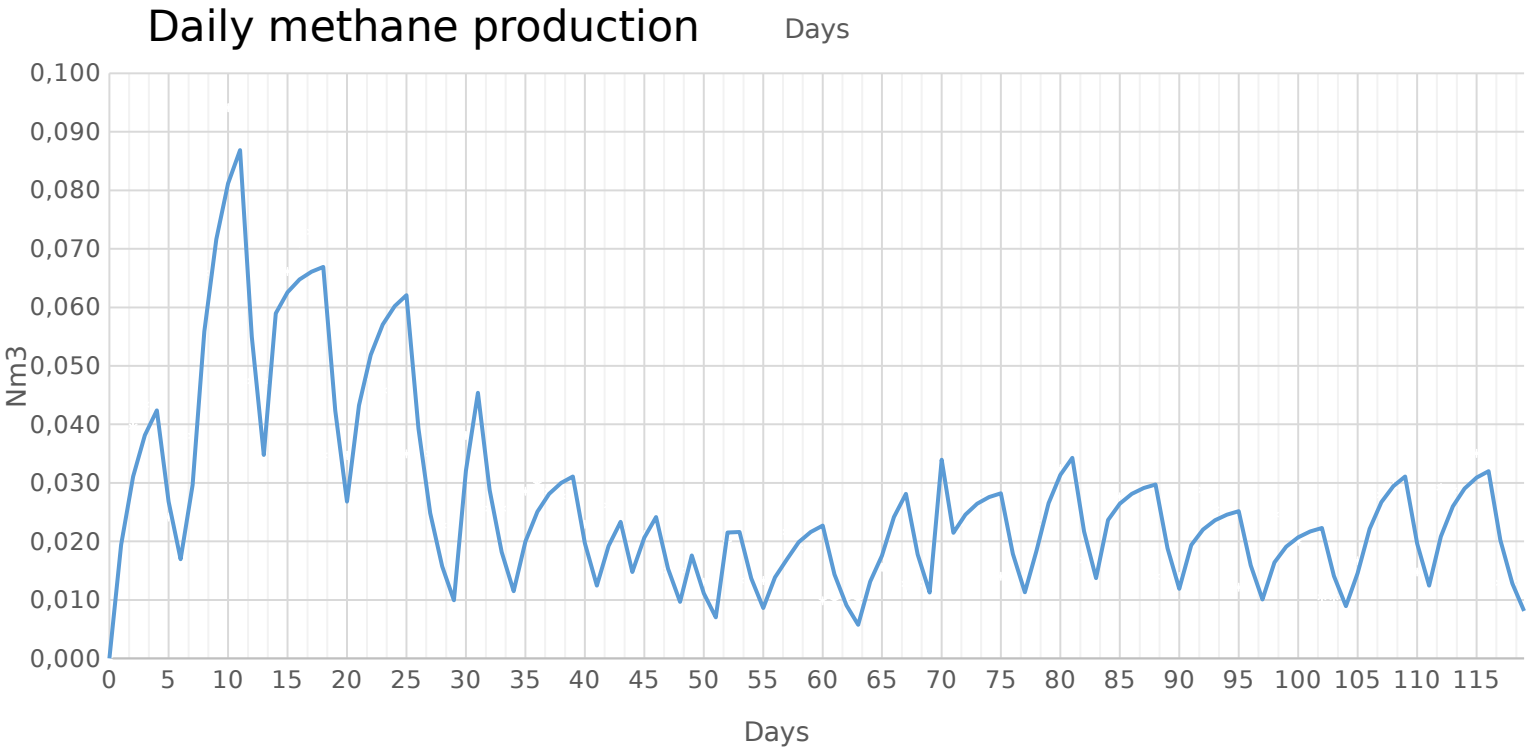
Secondary Sludge

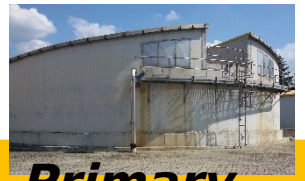
Pre-treatment: 90 °C - 1,5 h – 4g NaOH/100gST

Calibration



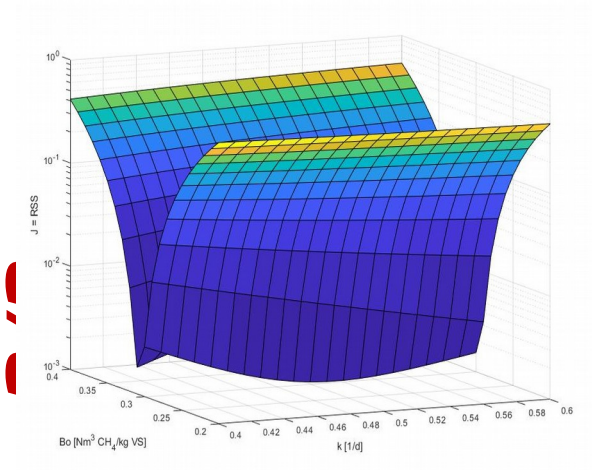


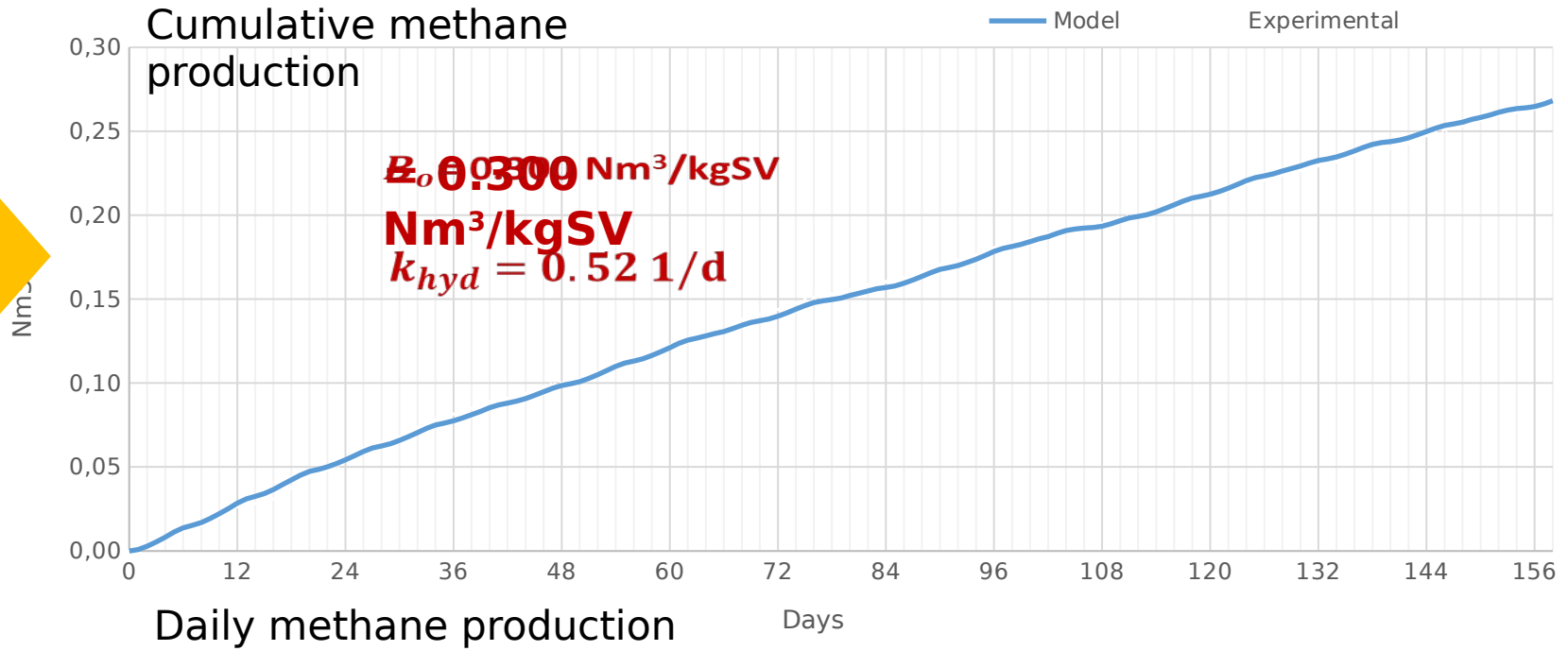


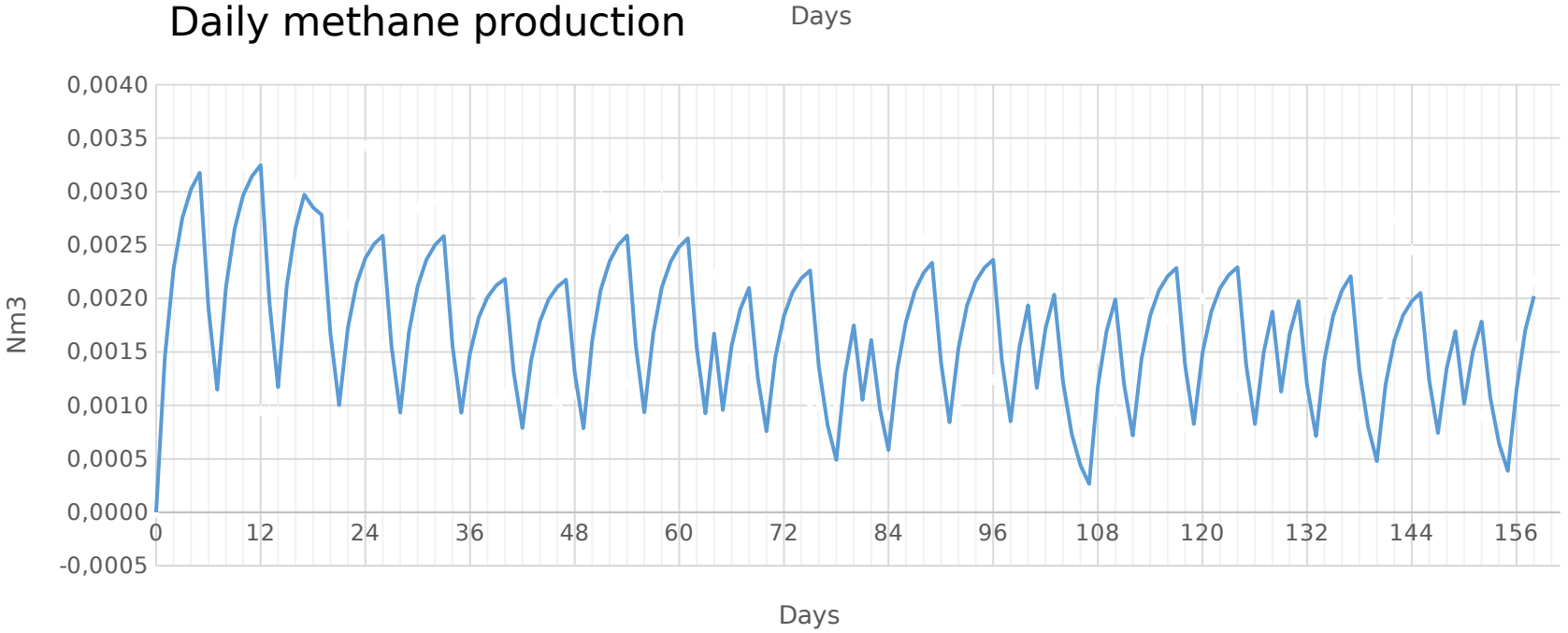


Primary sludge

Calibration



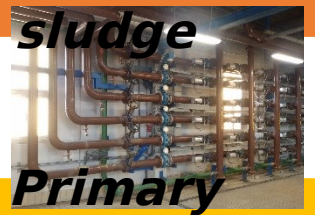




Validation

90 °C - 1,5 h – 4g NaOH/100gST

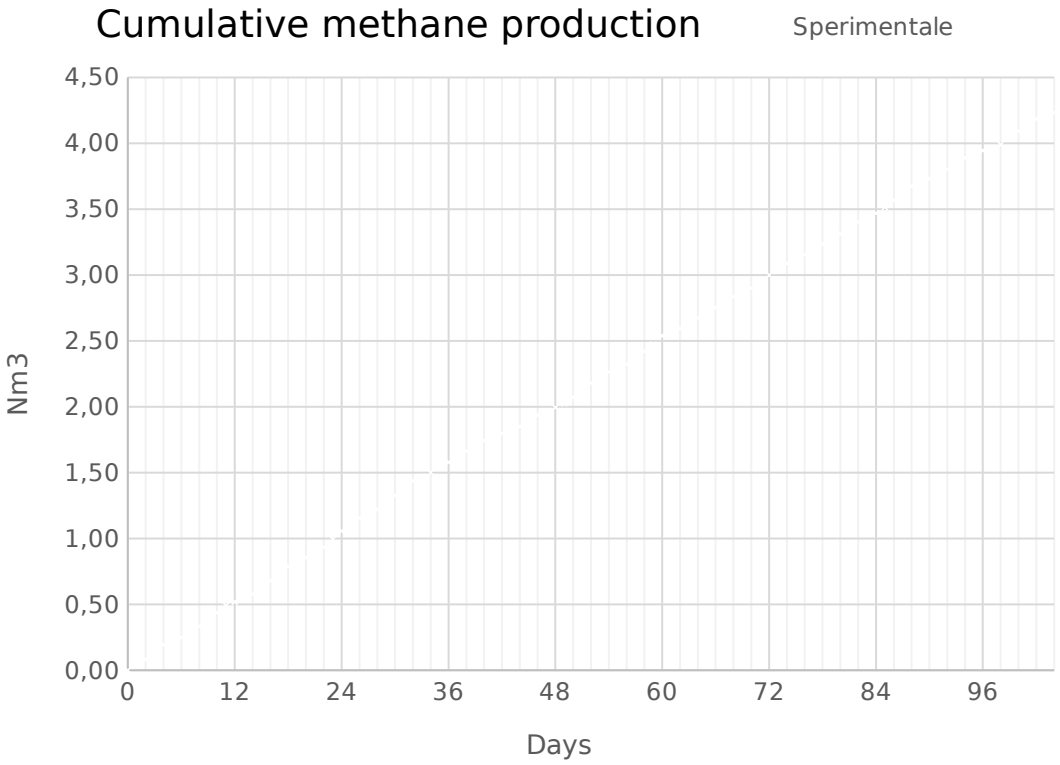
Secondary sludge

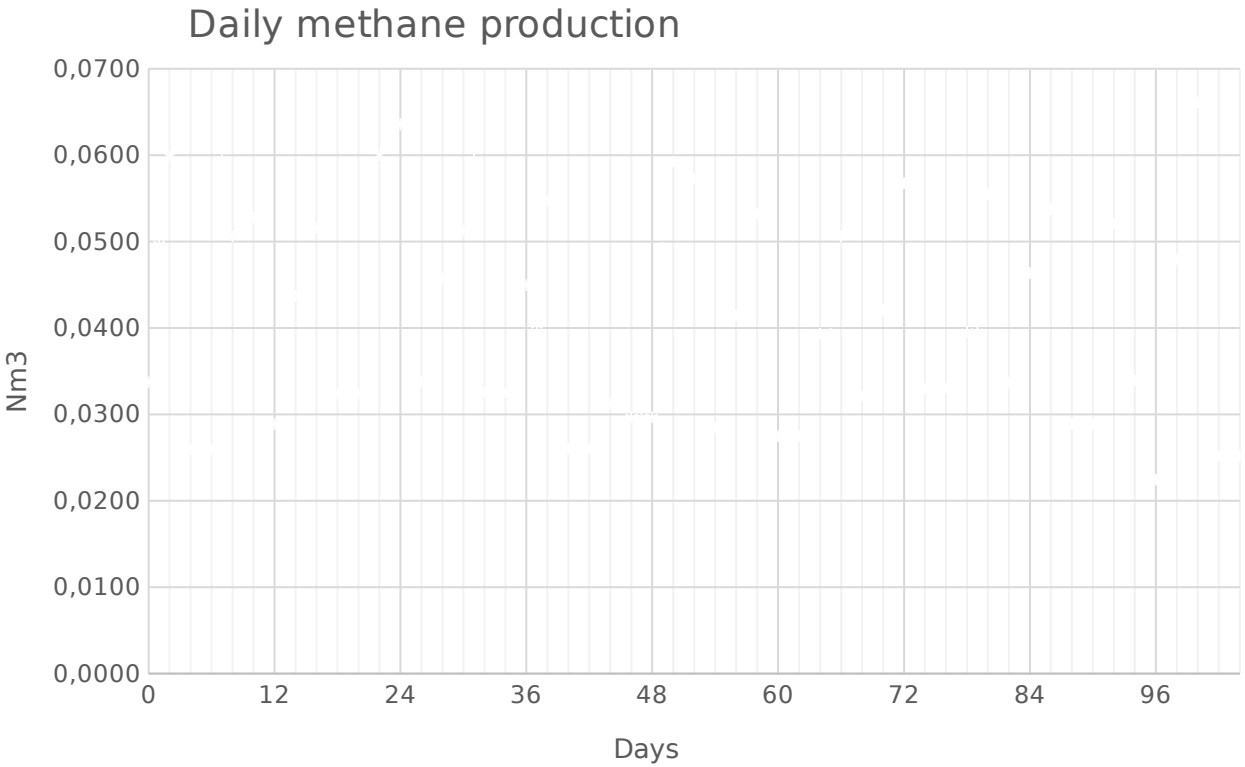


Primary sludge

50 %

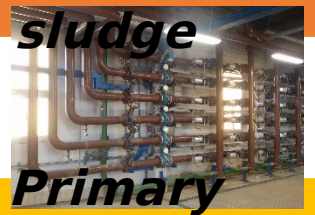
50 %





Validation

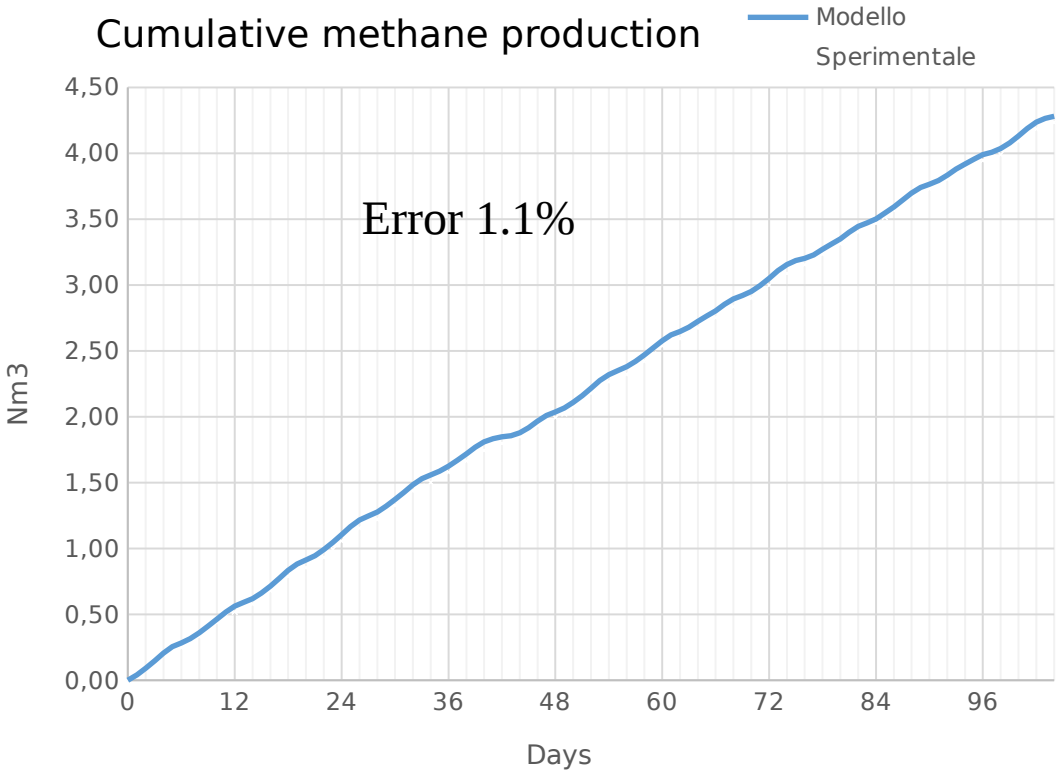
Secondary sludge

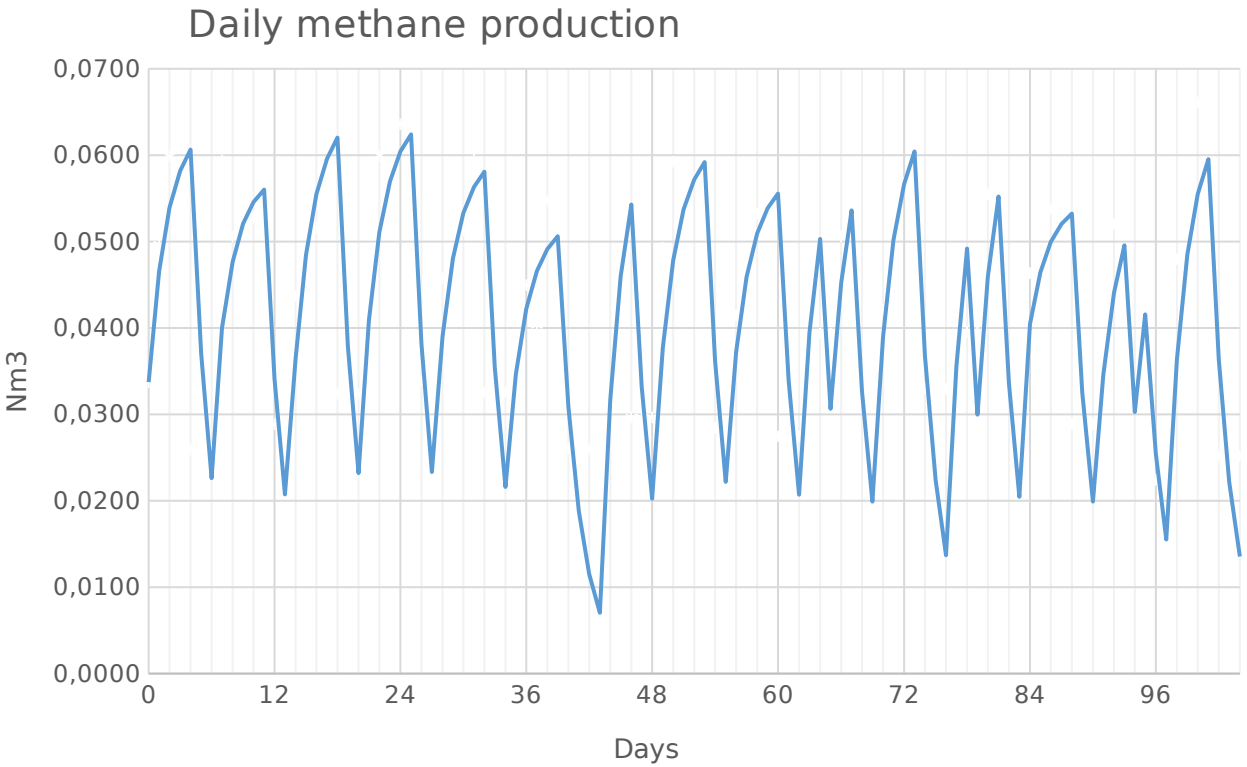


$B_o = 0.250\ Nm^3/kgVS$ $k_{hyd} = 0.46\ 1/d$

Primary sludge

$B_o = 0.300\ Nm^3/kgVS$ $k_{hyd} = 0.52\ 1/d$





WAS A.D. in WWTP Castiglione Torin

smat gruppo

Present conditions

WAS
Mesophilic AD 38 °C

k = 0.09 ***1/d***
B_o = 0.147 ***Nm³/kg VS***

B_{20d} = 0.09
Nm³/kg VS

$$B = \left(1 - \frac{1}{1 + k \cdot HRT}\right) B_o$$

WAS A.D. in WWTP Castiglione Torin

smat gruppo

Present conditions

WAS
Mesophilic AD 38°C

k = 0.09 ***1/d***
B_o = 0.147 ***Nm³/kg VS***

B_{20d} = 0.09
Nm³/kg VS

Scenario 1

WAS
Pretreatment + AD 38°C

NaOH 4g/100g TS
90 °C, 1,5h

k = 0.46 ***1/d***
B_o = 0.250 ***Nm³/kg VS***

B_{20d} = 0.226
Nm³/kg VS

+ 144 %

WAS A.D. in WWTP Castiglione Torin

smat gruppo

Present conditions

WAS

Mesophilic AD 38 °C

k = 0.09 ***1/d***

B_o = 0.147 ***Nm³/kg VS***

B_{20d} = 0.09

Nm³/kg VS

Scenario 1

WAS

Pre-treatment + AD 38 °C

NaOH 4g/100g TS

90 °C, 1,5h

k = 0.46 ***1/d***

B_o = 0.250 ***Nm³/kg VS***

B_{20d} = 0.226

Nm³/kg VS

+ 144 %

Scenario 2

WAS

Thermophilic AD 55 °C

k = 0,360 ***1/d***

B_o = 0,228 ***Nm³/kg VS***

B_{20d} = 0,193

Nm³/kg VS

+ 108 %

Yesterday

Conclusions:

- The proposed first order kinetic model can be used as a tool in order to obtain a good estimation of the couple of parameters Bo and k .
- The thermo-alkali treatment improved the biomethane potential by 70.1 %;
- The raw secondary sludge is slowly biodegradable ($k = 0.09\ d^{-1}$) but the thermo-alkali treatment increased the hydrolysis constant by 447%;

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7th International Conference on Sustainable Solid Waste Management

25 – 28 June 2019

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Application of semi-continuous pilot-scale AD tests to assess biochemical methane potential and hydrolysis rate constant of raw and pre-treated sludge

Thank you for your attention!

(po[1], A.Cerutti[1], M.C. Zanetti[1], G. Scibilia[2], E. Lore

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