HERAKLION 2019

7th International Conference on Sustainable Solid Waste Management

26 – 29 June 2019

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Performance comparison between mesophilic and thermophilic anaerobic digestion processes carried out on waste activated sludge

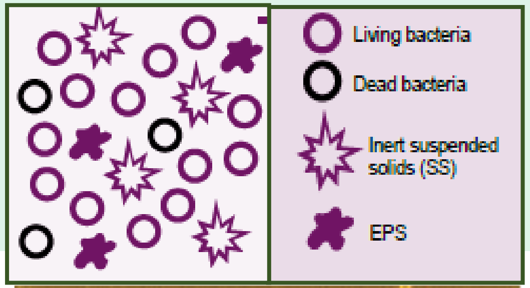
A. Cerutti[1], G. Campo[1], M.C. Zanetti[1], G. Scibilia[2], E. Lorenzi[2], B. Ruffino[1]

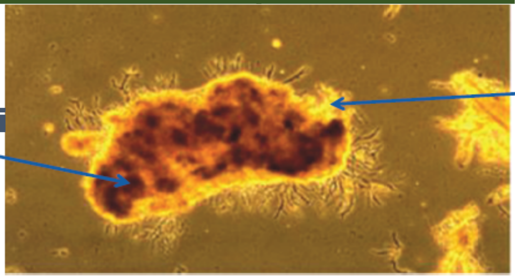
[1]Department Environment, Land and Infrastructure Engineering, Politecnico di Torino, Torino, I-10129, Italy

[2]Research Center, Società Metropolitana Acque Torino S.p.A., Viale Maestri del Lavoro, 4 – 10127 Torino, Italy

2 STRATEGIES

Waste Activated Sludge





Bacteri a
Dark-brown color

Extracellular Polymeric Substance (EPS)
Glowing color

from Shana et al., 2015

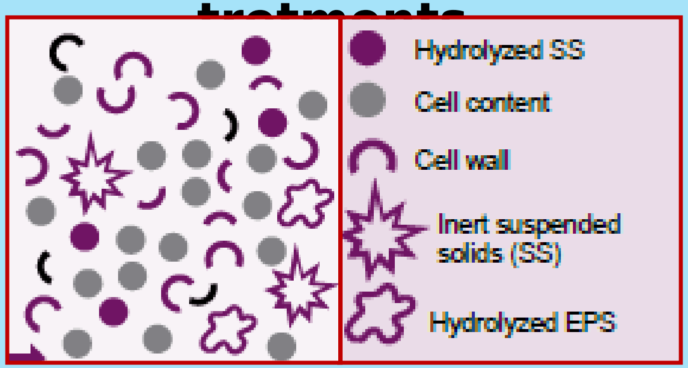
Low degradability

▼

Low efficiency of the AD process

- Low dewaterability

Pre / intermediate

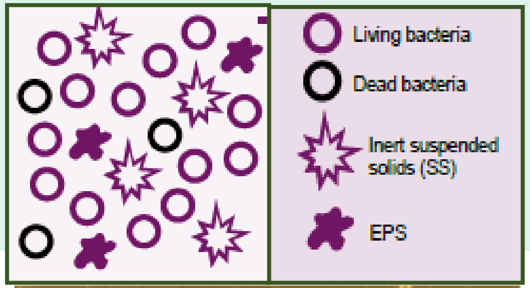


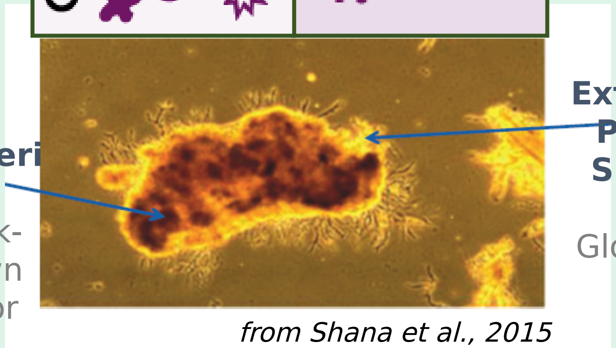
MESOPHILIC AD

http://www.cambi.com

2 STRATEGIES

Waste Activated Sludge





from Shana et al., 2015

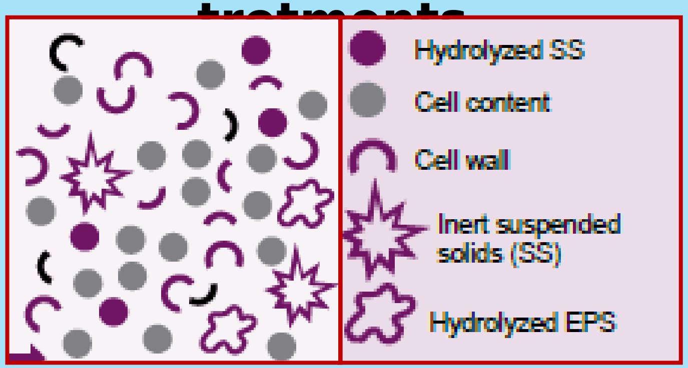
Low degradability

▼

Low efficiency of the AD process

- Low dewaterability

Pre / intermediate treatments



→ MESOPHILIC AD

?

→ **<u>THERMOPHILIC AD</u>**

In this presentation:

EXPERIMENTAL PHASE	MODELING PHASE Simplified Anaerobic Digestion Model 1 (ADM1)
Mesophilic AD of WAS in a 300L CSTR	Calibration Validation
Thermophilic AD of WAS in a 44L CSTR	Calibration
Thermophilic AD of WAS in a 300L CSTR	Validation

In this presentation:

EXPERIMENTAL PHASE	MODELING PHASE Simplified Anaerobic Digestion Model 1 (ADM1)
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Thermophilic AD of WAS in a 44L CSTR	Calibration
Thermophilic AD of WAS in a 300L CSTR	Validation

WAS

k: first order kinetics costant [*1/d*]

B_0: biomethane potential [*Nm³/kgVS*]

Mesophilic cond.

Thermophilic cond.

Experimental phase

MESOPHILIC
CONDITION 38°C, HRT 20 d

THERMOPHILIC
CONDITION 55°C, HRT 20 d

Pre-thickened WAS
(TS, VS, pH, FOS / TAC)
5 days / week

300 L
C.S.T.R.

Biogas
(CH_4, CO_2, O_2, Bal.)
5 days / week

Digestate
(TS, VS, pH, FOS / TAC)
5 days / week

Experimental phase

MESOPHILIC
CONDITION 38°C, HRT 20 d

THERMOPHILIC
CONDITION 55°C, HRT 20 d

Pre-thickened WAS
(TS, VS, pH, FOS / TAC)
5 days / week

44 L
C.S.T.R.

300 L
C.S.T.R.

Biogas
(CH_4, CO_2, O_2, Bal.)
5 days / week

Digestate
(TS, VS, pH, FOS / TAC)
5 days / week

Experimental phase

MESOPHILIC
CONDITION 38°C, HRT 20 d

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CONDITION 55°C, HRT 20 d

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300 L
C.S.T.R.

44 L
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Biogas
(CH_4, CO_2, O_2, Bal.)
5 days / week

300 L
C.S.T.R.

Digestate
(TS, VS, pH, FOS / TAC)
5 days / week

Castiglione Torinese SMAT WWTP

Sludge line: from pre-thickeners to digesters

Static pre-thickener

WAS sample
Thickened from 2,5 to 3% TS

Mesophilic inoculum

Thermophilic digesters

Thermophilic inoculum

Experimental phase

B_{exp}, VS_{exp} removal

Modeling phase

k, B_0

Industrial design (optimal HRT)

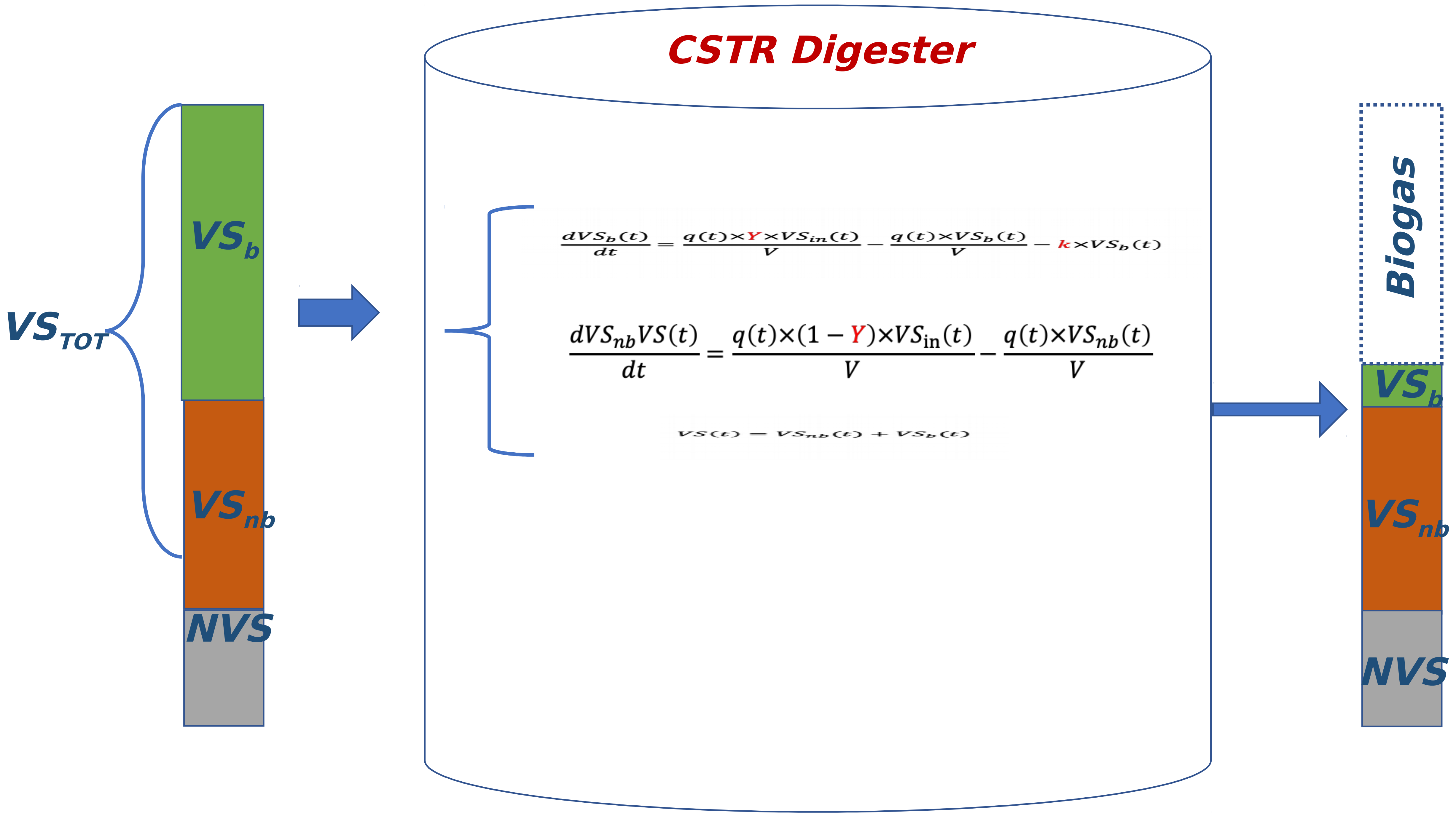
$$B = \left(1 - \frac{1}{1 + k\,HRT}\right)B_o$$

aerobic Digestion Model 1 (ADM1) *(Batstone DJ. et al., 2002)*

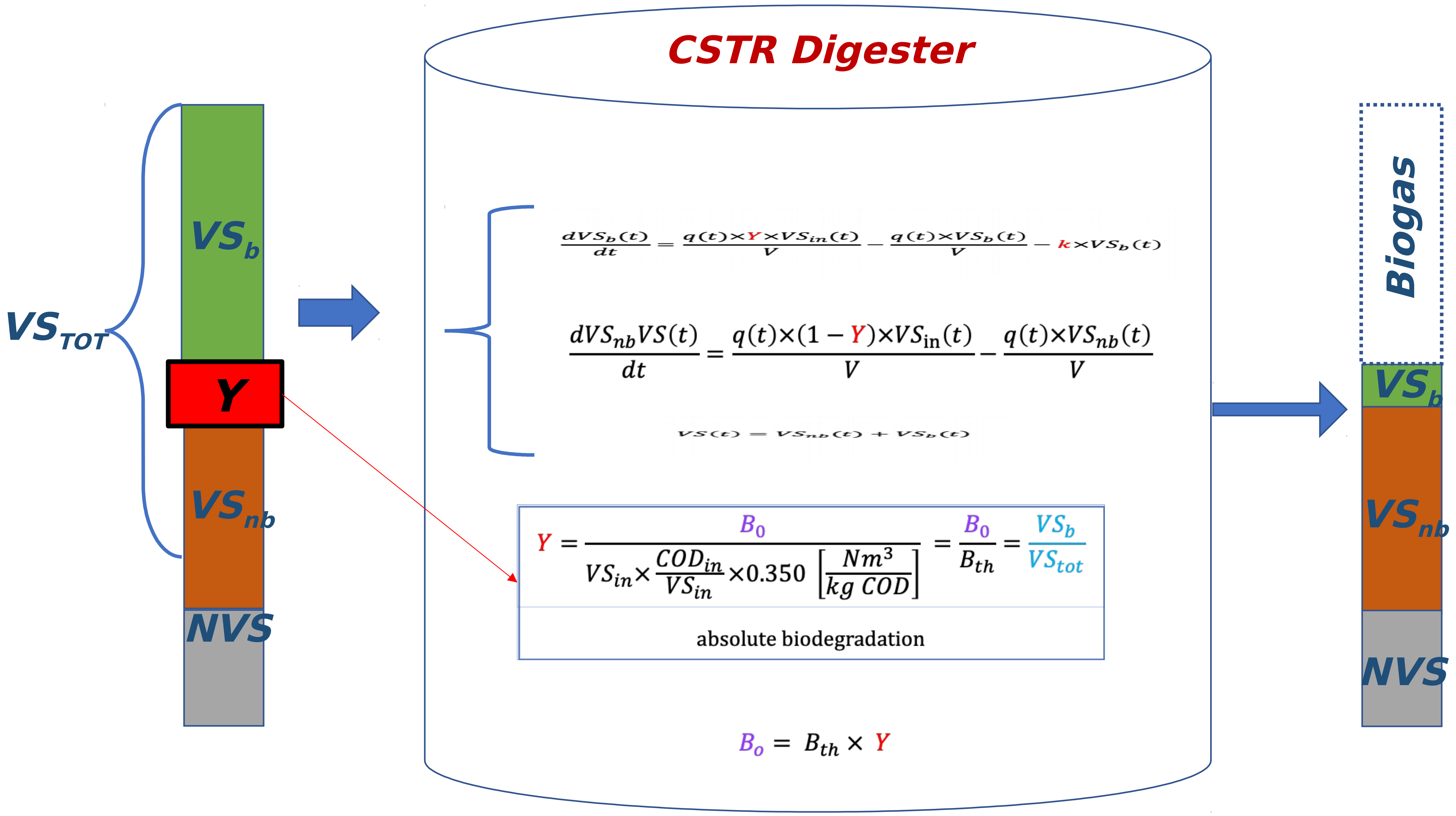
ng hypothesis:

lysis is assumed to be the limiting step of AD □ methane production can be modelled through a first order

$$\begin{cases} \frac{dVS_b(t)}{dt} = \frac{q(t)\times VS_{b\,in}(t)}{V} - \frac{q(t)\times VS_b(t)}{V} - k \times VS_b(t) \\ B_d(t) = VS_b(t)\times k \times B_0 \times V \end{cases}$$

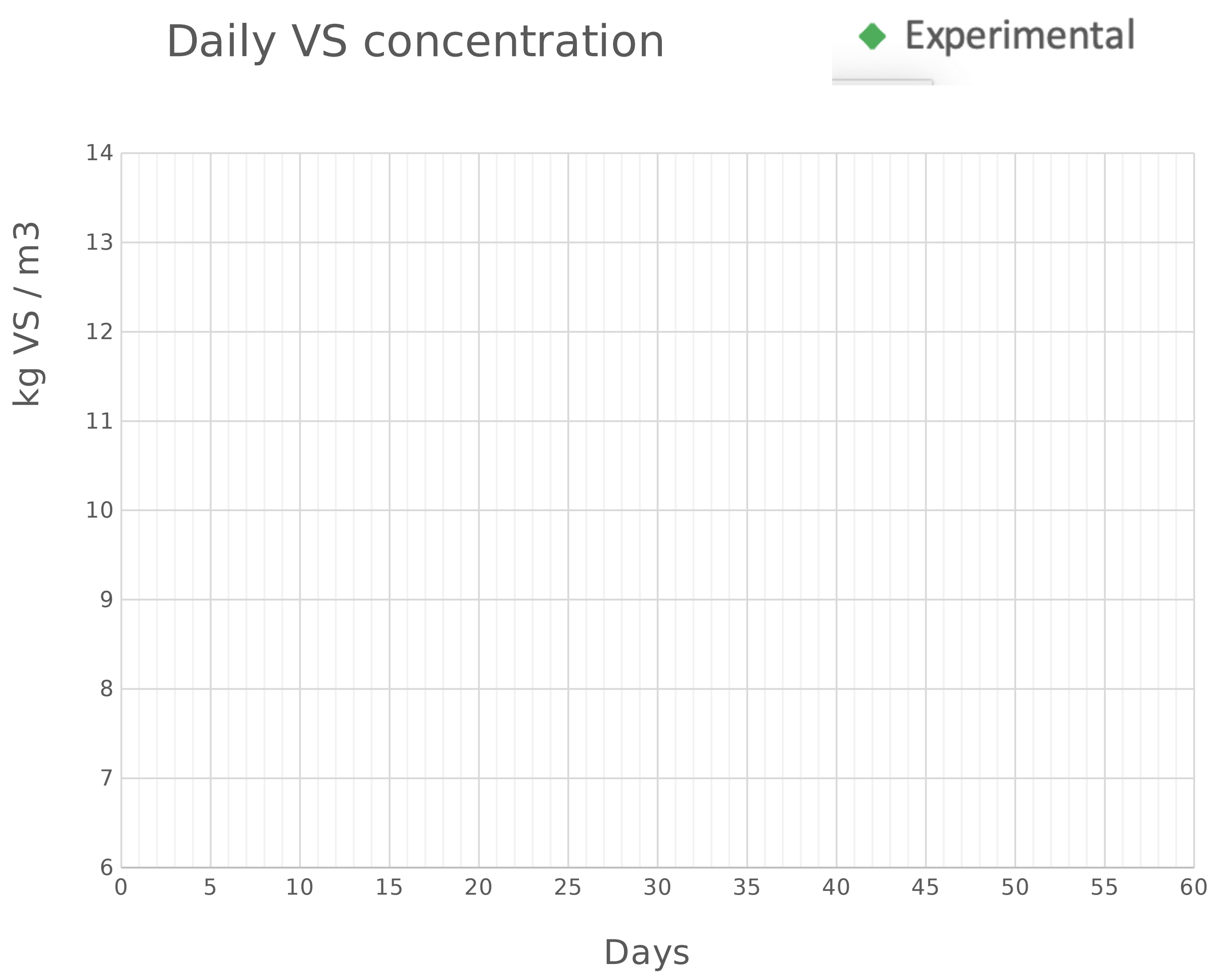


CSTR Digester
VSTOT
VSb
VSnb
NVS
$\frac{dVS_b(t)}{dt} = \frac{q(t)\times Y\times VS_{in}(t)}{V} - \frac{q(t)\times VS_b(t)}{V} - k\times VS_b(t)$
$\frac{dVS_{nb}VS(t)}{dt} = \frac{q(t)\times(1-Y)\times VS_{in}(t)}{V} - \frac{q(t)\times VS_{nb}(t)}{V}$
$VS(t) = VS_{nb}(t) + VS_b(t)$
Biogas
VSb
VSnb
NVS



CSTR Digester
VS_{TOT}
VS_b
Y
VS_{nb}
NVS
$\frac{dVS_b(t)}{dt} = \frac{q(t)\times Y\times VS_{in}(t)}{V} - \frac{q(t)\times VS_b(t)}{V} - k\times VS_b(t)$
$\frac{dVS_{nb}VS(t)}{dt} = \frac{q(t)\times(1-Y)\times VS_{in}(t)}{V} - \frac{q(t)\times VS_{nb}(t)}{V}$
$VS(t) = VS_{nb}(t) + VS_b(t)$
$Y = \frac{B_0}{VS_{in}\times\frac{COD_{in}}{VS_{in}}\times 0.350\left[\frac{Nm^3}{kg\ COD}\right]} = \frac{B_0}{B_{th}} = \frac{VS_b}{VS_{tot}}$
absolute biodegradation
$B_o = B_{th}\times Y$
Biogas
VS_b
VS_{nb}
NVS

CALIBRATION



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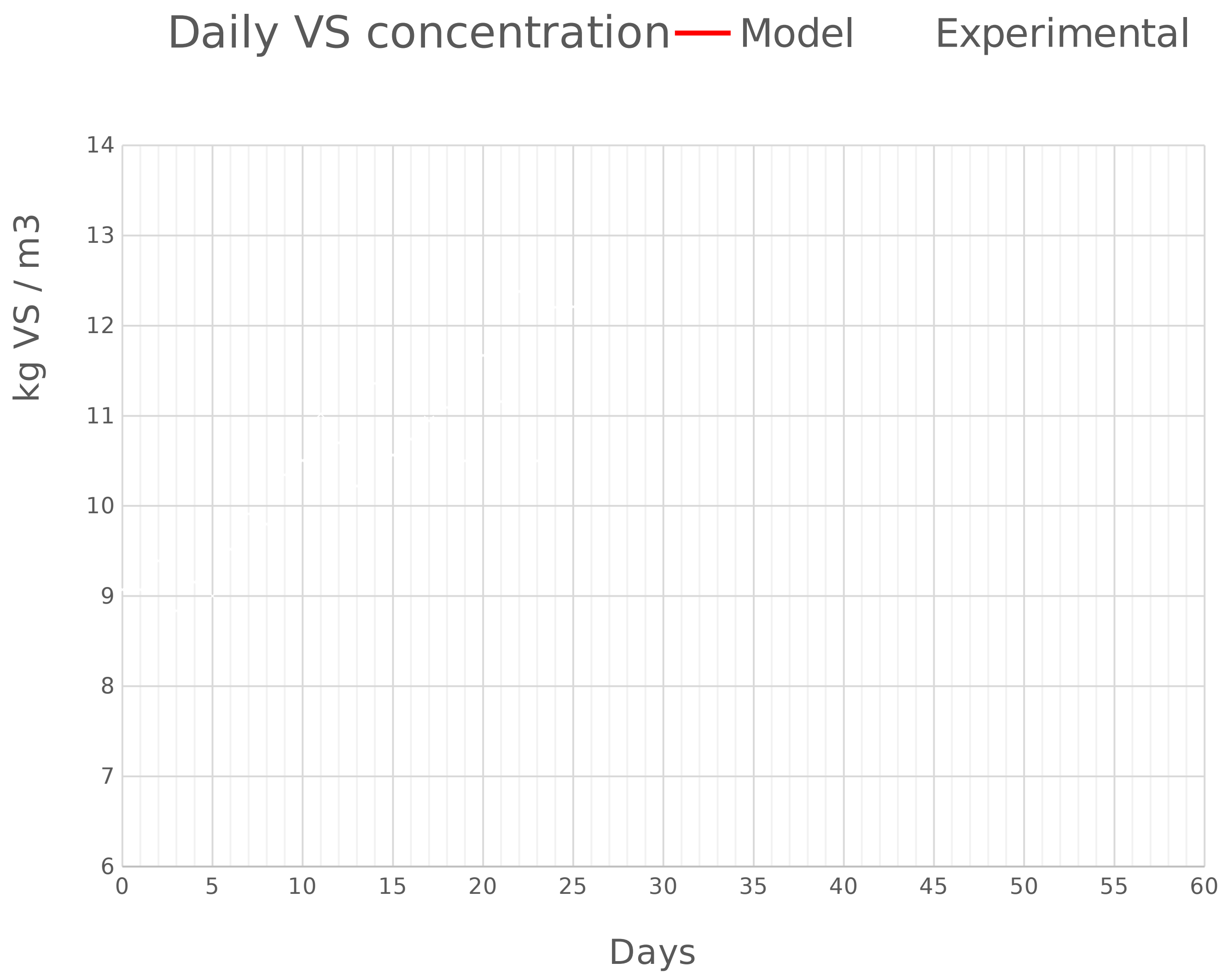
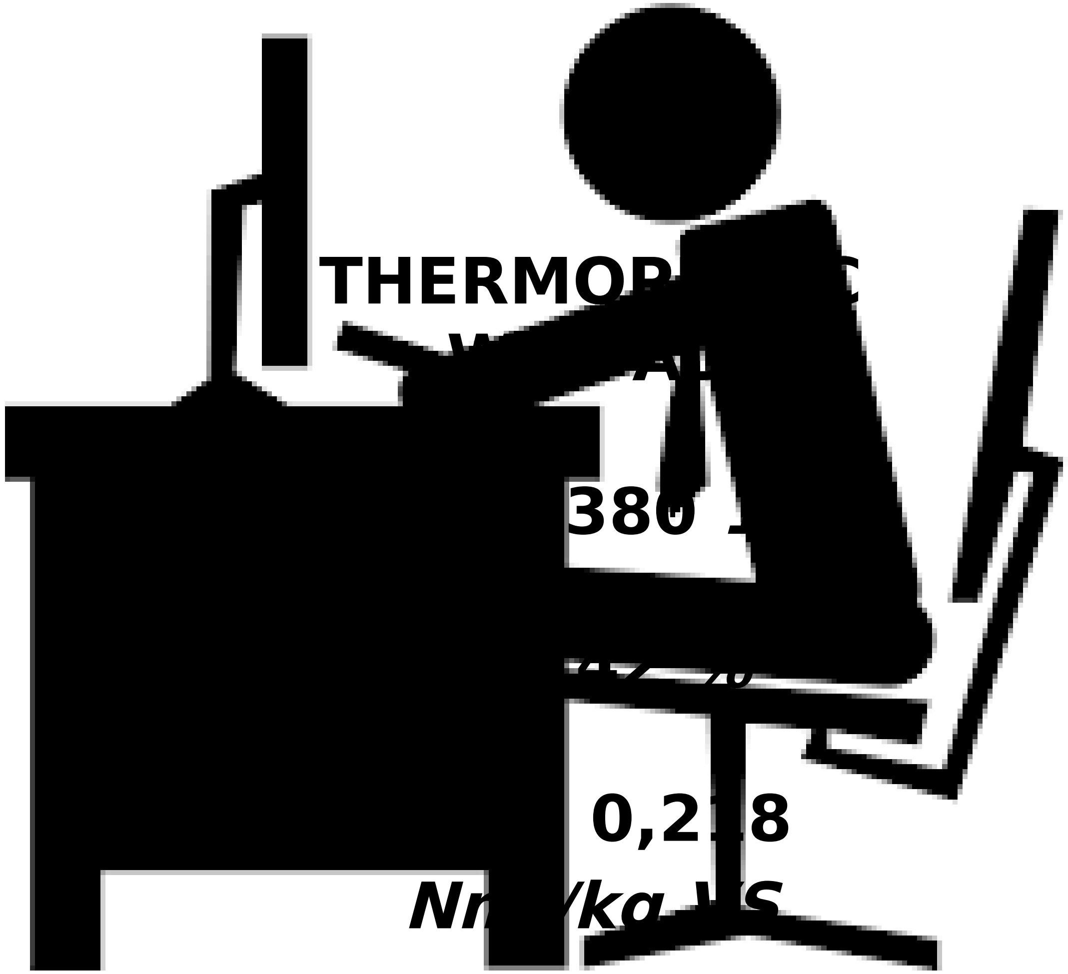
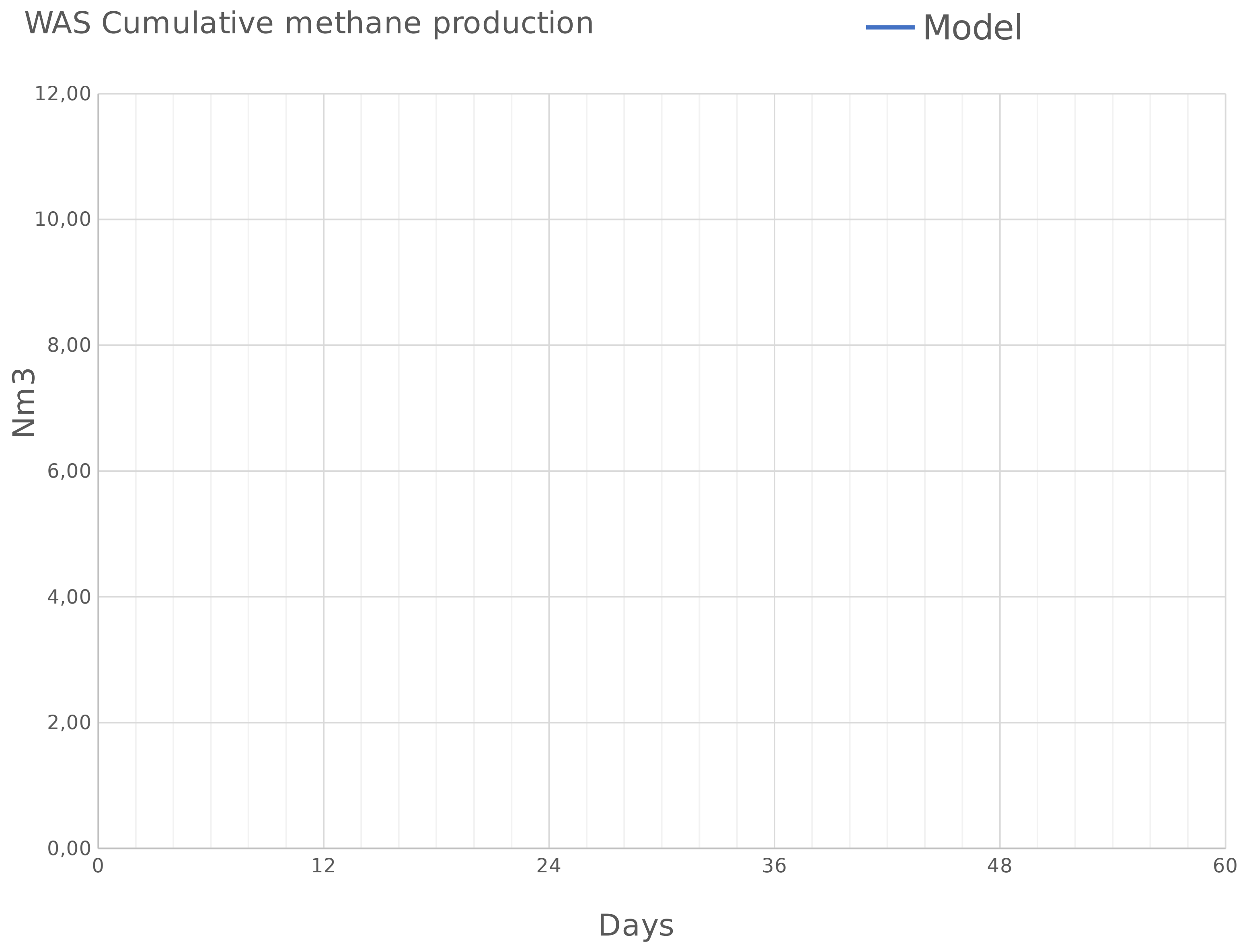
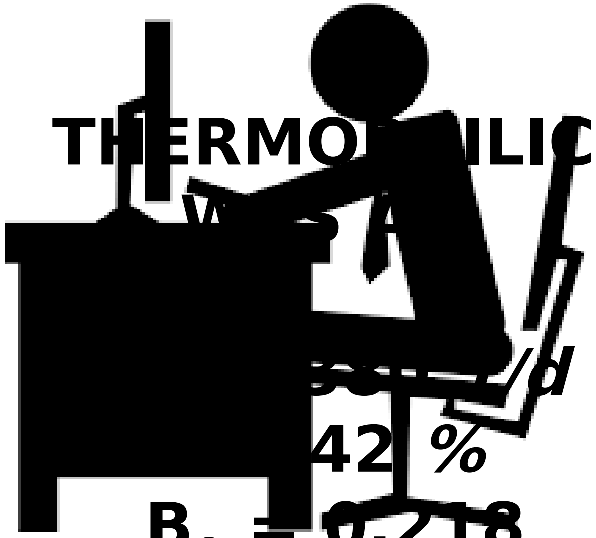




VALIDATION





THERMO...ILIC

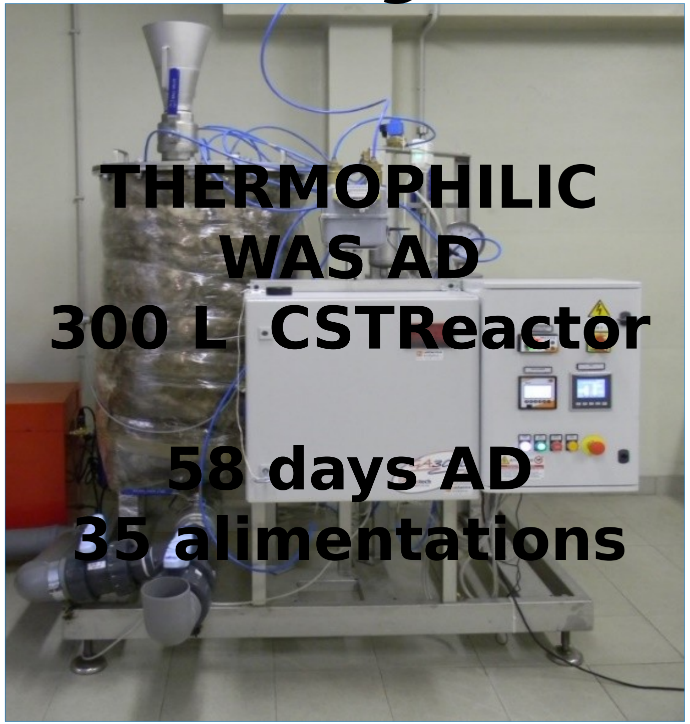
W...

...d

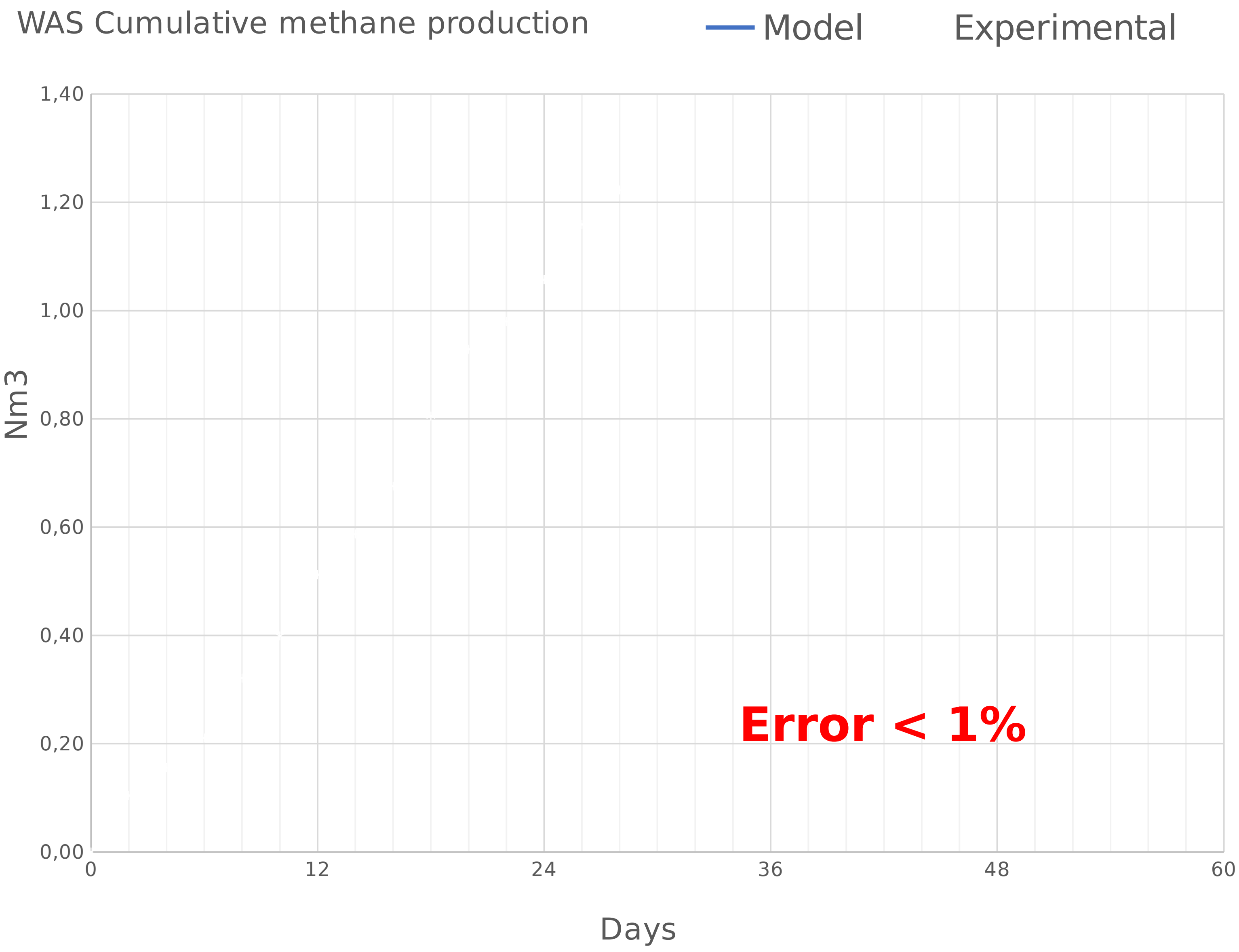
...42 %

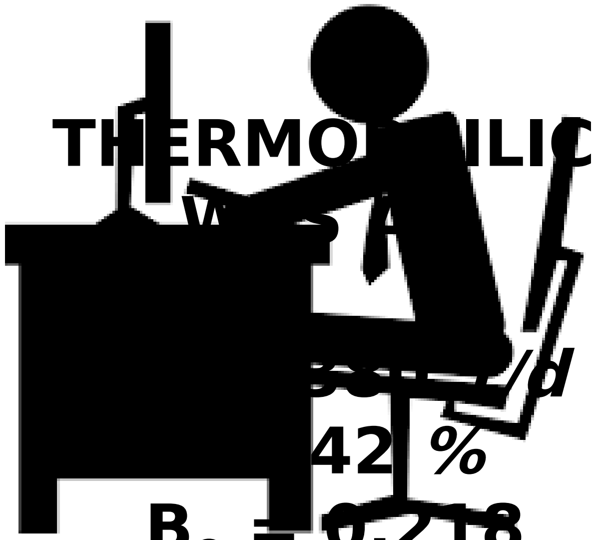
B_o = 0,218

Nm³/kg VS



VALIDATION



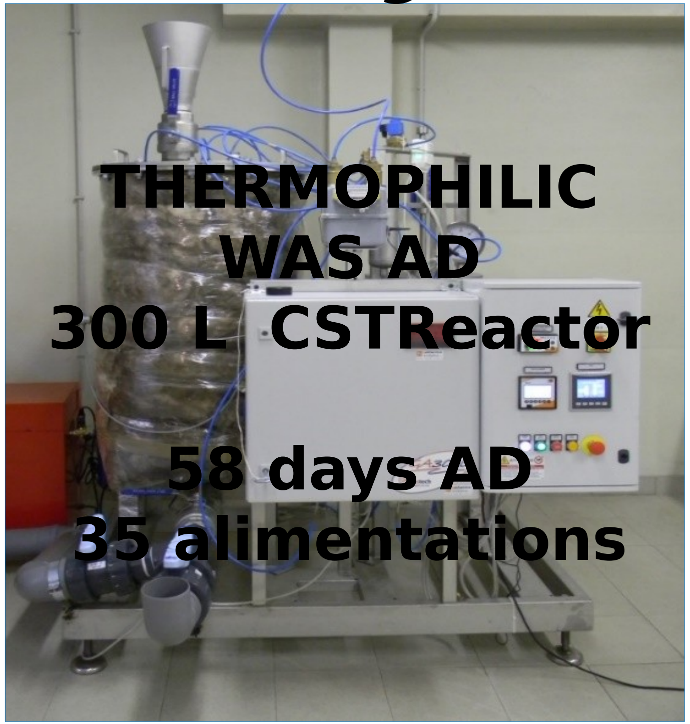


THERMOPHILIC

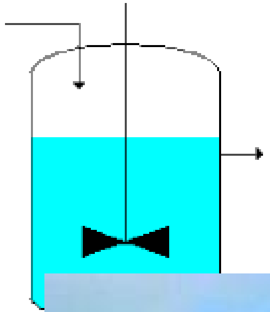
42 %

B_o = 0,218

Nm^3/kg VS

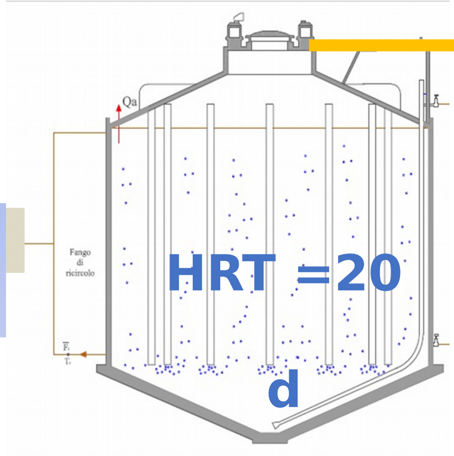


CST Reactor Steady state condition

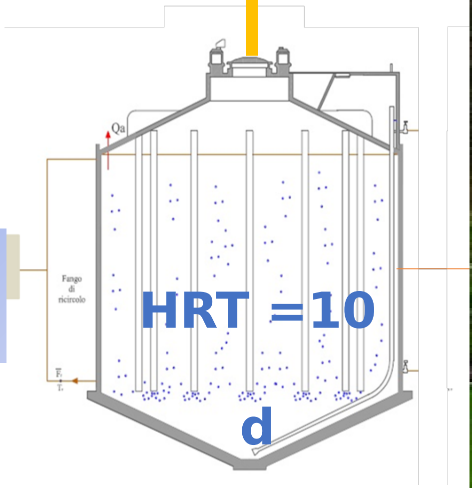


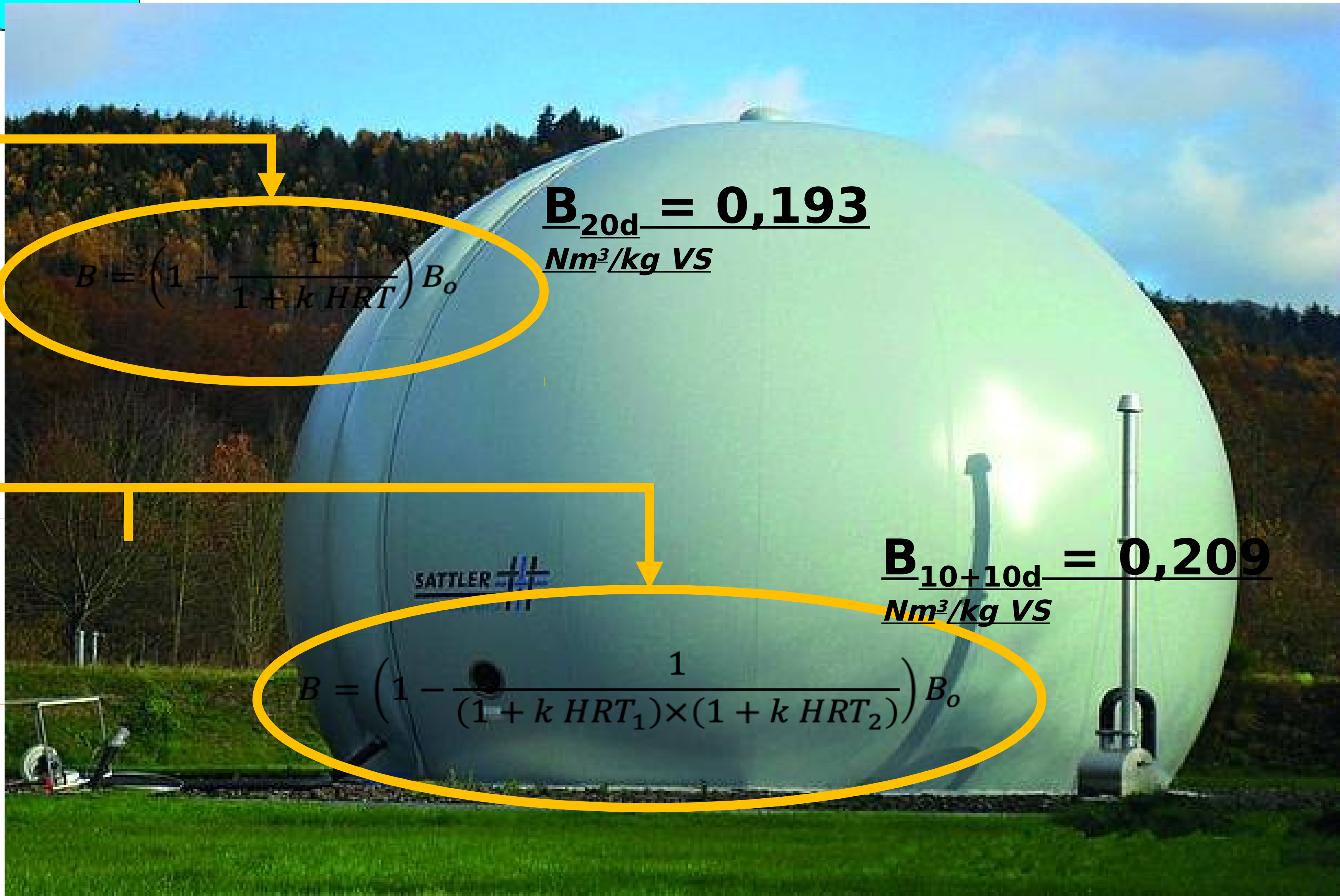
$$\frac{dS}{dt} = \frac{qS_0}{V} - \frac{qS}{V} - kS = 0 \rightarrow S = \frac{1}{1 + k\,HRT} S_o$$

1 stage A.D.



2 stage A.D.





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

B_{20d} = 0,193 *Nm³/kg VS*

$$B = \left(1 - \frac{1}{(1 + k\,HRT_1)\times(1 + k\,HRT_2)}\right) B_o$$

B_{10+10d} = 0,209 *Nm³/kg VS*

WAS A.D. in WWTP Castiglione Torin

Present conditions

WAS
Mesophilic AD 38 °C

K = 0,085 ***1/d***
B_o = 0,147 ***Nm³/kg VS***

B_{20d} = 0,090
Nm³/kg VS

WAS A.D. in WWTP Castiglione Torin

Present conditions

WAS
Mesophilic AD 38 °C

K = 0,085 *1/d*

B_o = 0,147 *Nm³/kg VS*

B_{20d} = 0,090 *Nm³/kg VS*

Scenario 1

WAS
Thermophilic AD 55 °C

K = 0,380 *1/d*

+ 347 %

B_o = 0,218 *Nm³/kg VS*

B_{20d} = 0,193 *Nm³/kg VS*

+ 108 %

WAS A.D. in WWTP Castiglione Torinese

smat gruppo

Present conditions

WAS
Mesophilic AD 38 °C

K = 0,085 ***1/d***

B_o = 0,147 ***Nm³/kg VS***

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Scenario 1

WAS
Thermophilic AD 55 °C

K = 0,380 ***1/d***

+ 347 %

B_o = 0,218 ***Nm³/kg VS***

B_{20d} = 0,193 ***Nm³/kg VS***

+ 108 %

Scenario 2

WAS
Pretreatment + AD 38 °C

NaOH 4g/100g TS
+
90 °C, [illegible],5h

TOMORROW

B_{20d} = 0,226 ***Nm³/kg VS***

+ 144 %

Conclusions

- The WAS AD in thermophilic condition improved the biochemical methane potential by 50 % related to the mesophilic condition;

- The raw WAS was only slowly biodegradable (k =0.085 d^{-1}) but the thermophilic condition increased the hydrolysis constant by 347 %;

- Due to the thermophilic condition; the WAS biodegradability rose from 28 to 42 %, with an increase of 50 %;

- In steady state condition with HRT equal to 20 days, the specific methane production increase in the order of 108 % related to the mesophilic condition.

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Thank you for your attention!

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smat gruppo

alberto.cerutti@polito.it

http://www.wearwe.polito.it

[1]Department Environment, Land and Infrastructure Engineering, Politecnico di Torino, Torino, I-10129, Italy

[2]Research Center, Società Metropolitana Acque Torino S.p.A., Viale Maestri