SwissBiogas.com
Additives for Desulphurisation in Anaerobic Digestion

Autark Investments and Projects AG
Dept. SwissBiogas.com
Baarerstrasse 75, CH-6300 Zug
Switzerland
www.swissbiogas.com

SwissBiogas.com presents:
SBGx desulphurisation and gas booster additive

v1.32

Autark Investments and Projects AG
Dept. SwissBiogas.com
Baarerstrasse 75, CH-6300 Zug
Switzerland
www.swissbiogas.com

Desulphurisation, why?

- Protects the CHP unit
- Protects the engines
- Raises the efficiency of the whole plant
- Lowers the operating costs
- Increases the operational safety

Autark Investments and Projects AG
Dept. SwissBiogas.com
Baarerstrasse 75, CH-6300 Zug
Switzerland
www.swissbiogas.com

Current desulphurisation methods:

- No reactor intervention
- Air injection

  Addition of
  - Ferric chloride, $FeCl_3$
  - Iron oxide-hydroxide, $FeO(OH)$
  - Iron oxide, Fe_xO_y

Autark Investments and Projects AG
Dept. SwissBiogas.com
Baarerstrasse 75, CH-6300 Zug
Switzerland
www.swissbiogas.com

Air injection, why not:

- Impairs fermentation and methane generation (Hinge 2014)
- Atmospheric nitrogen is unnecessarily added to the biogas (Ammonia)
- Excessive introduction of oxygen leads to formation of corrosive sulphurous acid
- % O_2 higher than 0.9% before CHP has a negative effect on efficiency of CHP
- Sulphur deposits formed in the fermenter gas compartment break off from time to time and drop into the substrate
- Risk of explosion
- Increased corrosion: $S + O_2 + H_2O \rightarrow H_2SO_4$
- The air flow should be controlled and adapted regularly:
  a) Less gas production but same air injection results in too much O_2 and dilution
  b) Higher gas production with same air injection results in too less O_2 with weak desulphurisation effect

Autark Investments and Projects AG
Dept. SwissBiogas.com
Baarerstrasse 75, CH-6300 Zug
Switzerland
www.swissbiogas.com

Ferric chloride, why not:

- Reduces volume of produced biogas (12% - 32%)
  (Dentel 1982, Johnson 2003, Smith 2008, 2009, Dauknys 2011)
- Forms HCl which penetrates the bacterial membrane
- Classified as dangerous substance
- Considered a corrosive substance
- Releases chlorides during desulphurisation → More corrosive than H_2S

CORROSIVE

IRRITANT

Autark Investments and Projects AG
Dept. SwissBiogas.com
Baarerstrasse 75, CH-6300 Zug
Switzerland
www.swissbiogas.com

Iron oxide-hydroxide, why not:

- **Iron oxide-hydroxide binds metals.**
  These materials are known to bind a wide range of other compounds from water, including trace metals, arsenic, selenium, silicate, and organics. Metals such as manganese, cobalt, nickel, and zinc are known to bind to iron oxide hydroxide in simulated seawater solutions. It has also been claimed that the binding of copper and zinc by natural iron oxide-hydroxide sediments exerts a powerful control on the concentration of copper and zinc in polluted rivers and estuaries. Although not studied in seawater, it has also been observed that phosphate binding by iron oxide-hydroxide actually increases its binding of copper, cadmium, and nickel in freshwater.

- Reference : http://www.reefkeeping.com/issues/2004-11/rhf/

Autark Investments and Projects AG
Dept. SwissBiogas.com
Baarerstrasse 75, CH-6300 Zug
Switzerland
www.swissbiogas.com

Iron oxide, why yes:

- Eliminates struvite formation
- Lowers H_2S very effectively
- Increases methane production
- Prevents corrosion of plant and CHP
- Reduces HRT

Autark Investments and Projects AG
Dept. SwissBiogas.com
Baarerstrasse 75, CH-6300 Zug
Switzerland
www.swissbiogas.com

What happens (inside the reactor):

$$2Fe^{3+} + H_2S \rightarrow 2Fe^{2+} + S + 2H^{+} \quad (1)$$

$$2Fe^{2+} + (1/2)\ O_2 + H_2O \rightarrow 2Fe^{3+} + 2OH^{-} \quad (2)$$

SwissBiogas.com

Additives for Desulphurisation in Anaerobic Digestion

Autark Investments and Projects AG
Dept. SwissBiogas.com
Baarerstrasse 75, CH-6300 Zug
Switzerland
www.swissbiogas.com

Comparison of desulphurisation methods, SBGx by SwissBiogas.com against others:

	SBGx	*Iron oxide*	*Iron oxide-hydroxide*	*Iron chloride*	*Air injection*
Investment into					
Storage and Handling	low	low	low	high	none
Dosing Equipment	none / low	none / low	medium	medium	medium
Risk of / to					
Exposure / Personnel	low	low	low	high	none
Explosion	low	low	low	low	high
Corrosion	low	low	low	high, HCl	high, H_2SO_4
Incompatibility	low	low	low	high	high
Gas Impurities	low	low	low	low	high
Reaction Products	none	none		HCl	H_2SO_4
Characteristics					
Reactive Content	> 60%	30% - 60%	10% - 15%	10% - 14%	none
Digestion Speed / Volume	high	low	low	high	low
Deposit Effect	high	high	medium	none	none
Methanogen Growth	increased	normal	normal	negative	negative
Gas Yield over Normal	higher	normal	normal	negative	negative
Trace Element Addition	not necessary	required	required	required	required
Shelf Life	> 12 months	> 12 months	< 12 months	< 12 months	none
Price per chem. Reaction	medium	high	medium	high	none

Autark Investments and Projects AG
Dept. SwissBiogas.com
Baarerstrasse 75, CH-6300 Zug
Switzerland
www.swissbiogas.com

The components of SBGx as base before individual adjustments to customers' requirements

Note: The industry-leading high content of reactive Fe_xO_y

SBGx	*[%]*
$FeO + Fe_2O_3$	> 70
MnO	< 1.0
C	< 0.5
Cr_2O_3	< 0.5
CaO	< 0.5
K_2O	< 0.5
Al_2O_3	< 0.5
SiO_2	< 0.5
ZnO	< 0.5
Na_2O	< 0.2
CuO	< 0.2
S	< 0.1
TiO_2	< 0.1
MgO	< 0.1
NiO	< 0.1
P_2O_5	< 0.1
MoO_3	< 0.05
V_2O_5	< 0.01
BaO	< 0.01
CoO	< 0.01
PbO	< 0.01
CdO	< 0.01
SnO_2	< 0.01
WO_3	< 0.01
Cl	< 0.01
SeO_2	< 0.01

SwissBiogas.com

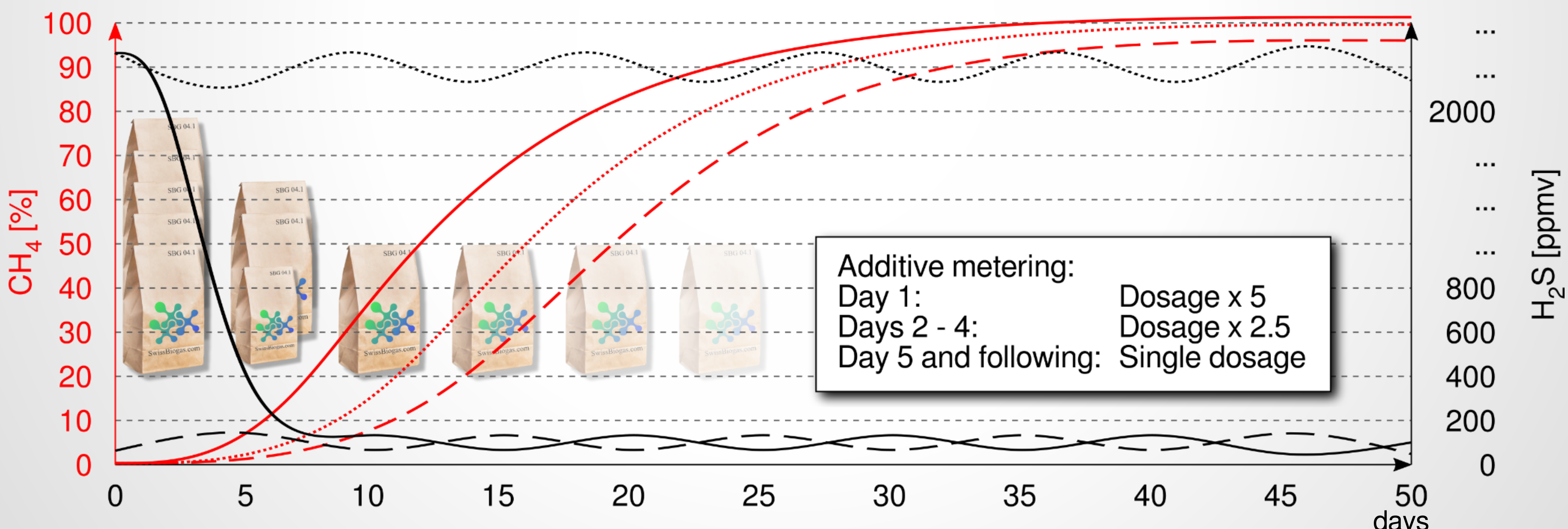
Additives for Desulphurisation in Anaerobic Digestion

Autark Investments and Projects AG
Dept. SwissBiogas.com
Baarerstrasse 75, CH-6300 Zug
Switzerland
www.swissbiogas.com

Sample application of SBGx in practice

Comparison of CH_4 and H_2S developments

Legend — CH_4 / H_2S
- SBGx treated, solid
- Untreated, dotted
- $FeCl_3$ treated, dashed



Note:
100% CH_4 = Total reclaimed CH_4 by untreated process within 50 days

Autark Investments and Projects AG
Dept. SwissBiogas.com
Baarerstrasse 75, CH-6300 Zug
Switzerland
www.swissbiogas.com

How we pack and ship:

Delivered in powder form, in
- 20 kg bags, or as per
- individual requirements

Please contact your agent for availability.

Autark Investments and Projects AG
Dept. SwissBiogas.com
Baarerstrasse 75, CH-6300 Zug
Switzerland
www.swissbiogas.com

Where we test:

FAIRY LAND 时代桃源

SwissBiogas.com
Additives for Desulphurisation in Anaerobic Digestion

Autark Investments and Projects AG
Dept. SwissBiogas.com
Baarerstrasse 75, CH-6300 Zug
Switzerland
www.swissbiogas.com

2017 Test results by specific waste category: *Kitchen Waste*

- Additive: EG 1117 (old naming convention)
- Duration: 51 days

Increase of methane production overall:

- Average: 13.5%
- High: 19.3%

Increase rate of methane production per unit VS:

- Average: 16.3%
- High: 23.2%

Speeding up of fermentation rate; Peak of daily methane production:

- Average w/o additive: Day 13, 183.1 ml/day
- Average w/ additive: Day 10, 200.5 ml/day
- High: Day 10, 206.7 ml/day

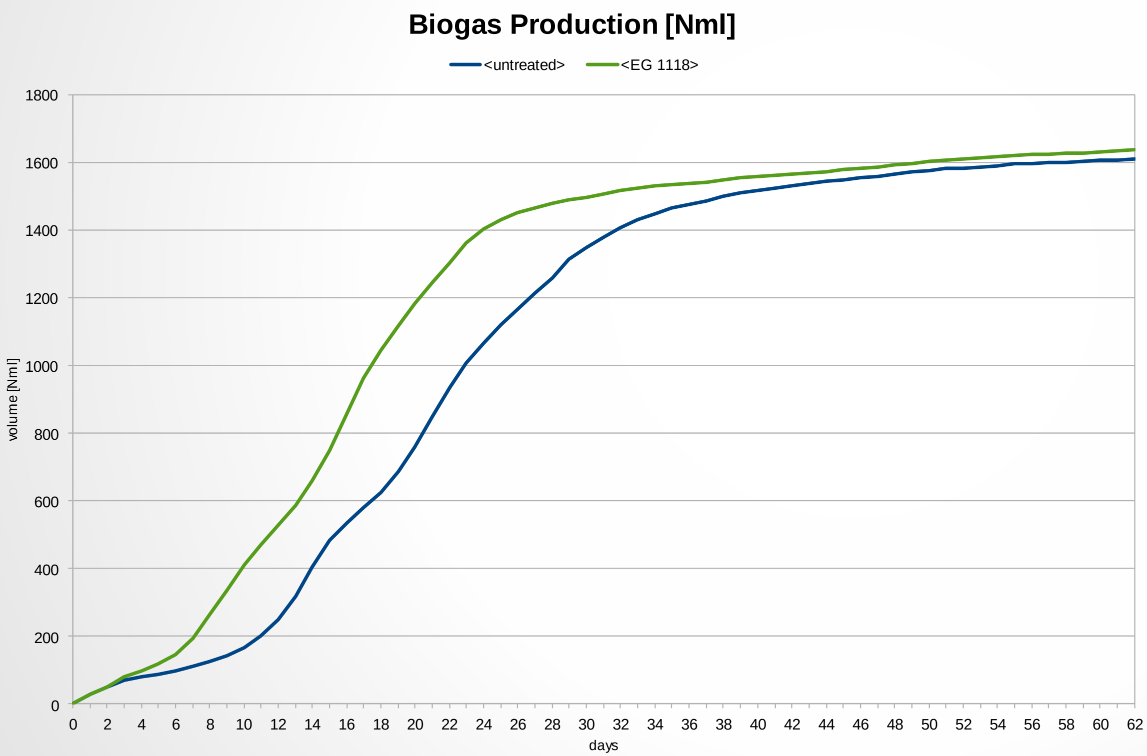
Remark: All results above achieved **within 43 days**!

Orig. report (2018, Q1) available upon request

FAIRY LAND 时代桃源

Autark Investments and Projects AG
Dept. SwissBiogas.com
Baarerstrasse 75, CH-6300 Zug
Switzerland
www.swissbiogas.com

2018 Effectivity test by specific waste category: *Corn Straw*



Slide 1 of 2

The maximum duration of the test periods was 79 days. As some tests were terminated between day 62 and 79, only the first 62 days are analysed.

During the first 30 days, the tests showed an increased effectivity in biogas production of the substrate treated with the SBG additive EG 1118 (green, old naming convention).

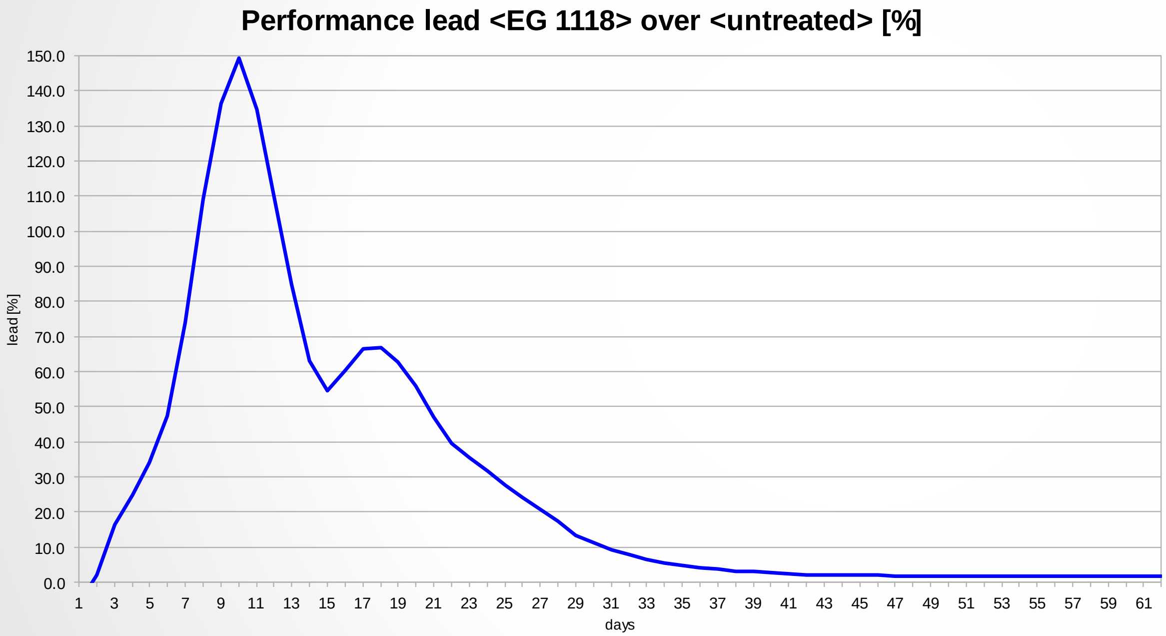
Several tests were performed and the graphs show the average (“<...>”) biogas production.

Total produced biogas with the untreated substrate after 62 days: 1609.7 Nml

FAIRY LAND 时代桃源

Autark Investments and Projects AG
Dept. SwissBiogas.com
Baarerstrasse 75, CH-6300 Zug
Switzerland
www.swissbiogas.com

2018 Effectivity test by specific waste category: *Corn Straw*



Slide 2 of 2

The graph shows the advantage [%] of the additive treated substrate over the untreated substrate.

If the total produced biogas with the untreated substrate after 62 days (1609.7 Nml) is defined as 100%, 90% was reached after:

- 34 days with the untreated substrate (1448.0 Nml)
- 26 days with the EG 1118 additive treated substrate (1449.6 Nml); Performance lead: 24.3%

If a short retention time in a reactor is key, the substrate treated with the EG 1118 additive has a significant advantage during the first 30 days. (see above)
Even at day 30, the EG 1118 additive treated substrate still has a lead of 11.1% in biogas production over the untreated substrate.

- untreated: 1347.1 Nml (83.7% of 1609.7 Nml)
- EG 1118: 1497.2 Nml (93.0% of 1609.7 Nml)

FAIRY LAND 时代桃源

2018 Test at a German biogas plant (EG 1118, old naming convent.)

	Input					Output				
Duration	Liq. Pig Man. [kg]	Grain [kg]	Maize [kg]	Recirculate [kg]	Total [kg]	CH_4 [Vol%]	CO_2 [Vol%]	O_2 [Vol%]	H_2S [ppm]	Energy [kWh]
5.9-16.9 12 days prio	18'639.00 (40.95%)	551.00 (1.21%)	26'330.00 (57.84%)	77'377.00	122'897.00	51.00	42.00	0.90	108.00	12'307.00
27.10-7.11 last 12 days	14'894.00 (37.14%)	495.00 (1.23%)	24'708.00 (61.62%)	75'854.00	115'951.00	50.00	48.00	1.10	77.00	12'999.00
Change [%]	*-20.09*	*-10.16*	*-6.16*	*-1.97*	***-5.65***	*-1.96*	*14.29*	*22.22*	***-28.70***	***5.62***

Methane potential calculation, based on "Biogas yield by substrate", page 815
Production from selected plants and by-products:

Substrate	Biogas [m³/t]	CH_4 ratio [%]	CH_4 [m³/t]
Pig Slurry:	500	65	325.0
Grain Decoction:	560	66	369.6
Maize Silage:	580	52	301.6

Source: *THE EFFECT OF SUBSTRATE ON THE AMOUNT AND COMPOSITION OF BIOGAS IN AGRICULTURAL BIOGAS PLANT*
Nr III/2/2015, POLSKA AKADEMIA NAUK, Oddział w Krakowie, s. 809–818
Komisja Technicznej Infrastruktury Wsi
By: *Joanna Kazimierowicz, Bialystok University of Technology*
Link: *http://dx.medra.org/10.14597/infraeco.2015.3.2.065*

Comparison of the reactor's methane potential based on the substrate input:

Duration	Pig Slurry [m³]	Grain Dec. [m³]	Maize [m³]	Recirculate [m³]	Total CH_4 [m³]
5.9-16.9	6'057.68	203.65	7'941.13	24'141.99	38'344.44
27.10-7.11	4'840.55	182.95	7'451.93	23'600.56	36'075.99
Change [%]	*-20.09*	*-10.16*	*-6.16*	*-2.24*	***-5.92***

→

Assumption:
The recirculate has the same mix ratio as the freshly added substrate.

If a potential of 38,344.44 m³ of CH_4 result in measured 12,307.00 kWh of energy, then a potential of 36,075.99 m³ of CH_4 should mathematically result in 11,578.92 kWh (-,5.92%) of energy, without additives.

Duration		Energy w/o additives [kWh]		Energy w/ additives [kWh]
5.9-16.9		12'307.00		-------
27.10-7.11	*calculated:*	**11'578.92**	*measured:*	**12'999.00**
Change [%]		*-5.92*		-------

→

Effect of the SwissBiogas.com additives:
Increase from 11,578.92 kWh to 12,999.00 kWh: 12.26%

Autark Investments and Projects AG
Dept. SwissBiogas.com
Baarerstrasse 75, CH-6300 Zug
Switzerland
www.swissbiogas.com

For references please contact:

FAIRY LAND 时代桃源

Fairyland Environmental Technology
3rd floor, Deshi Building
No. 9 East Road
Shangdi, Haidian district, Beijing
China
Tel.: 010-62975118
Email: fairyland@fairyland.com.cn