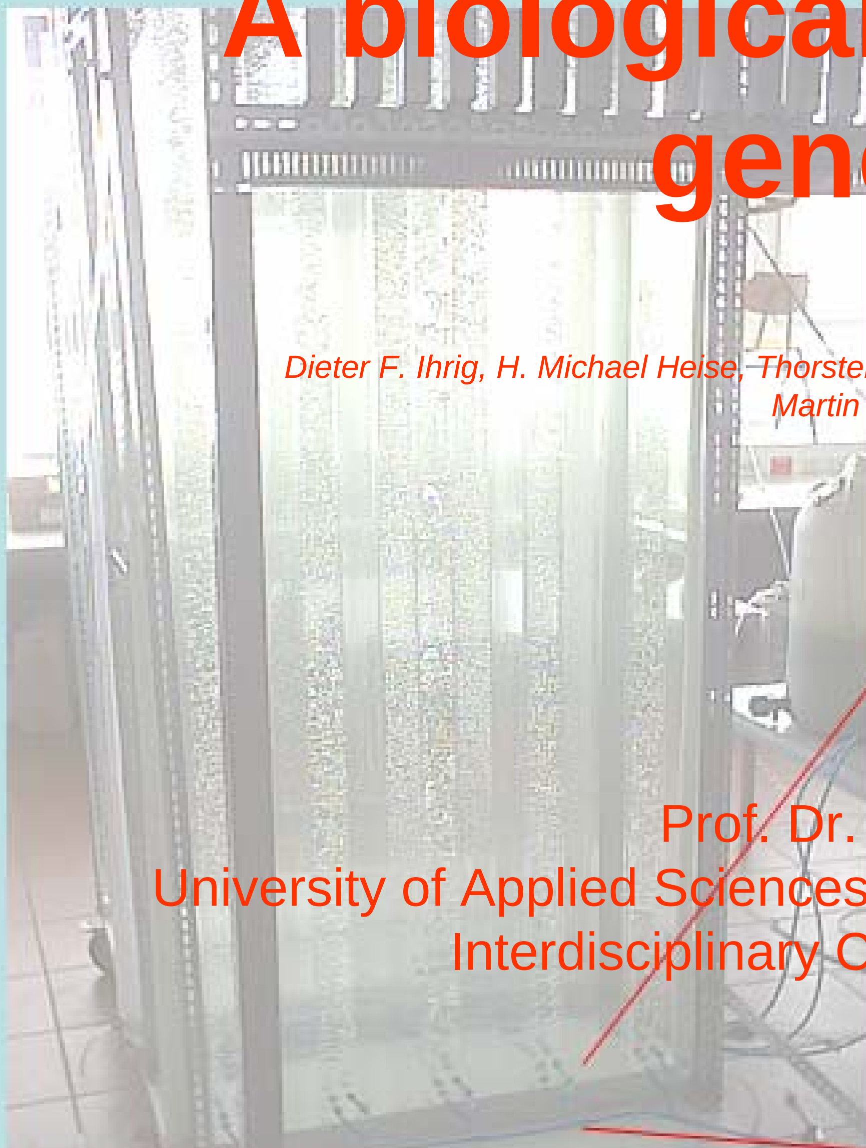
A biological solar energy generator



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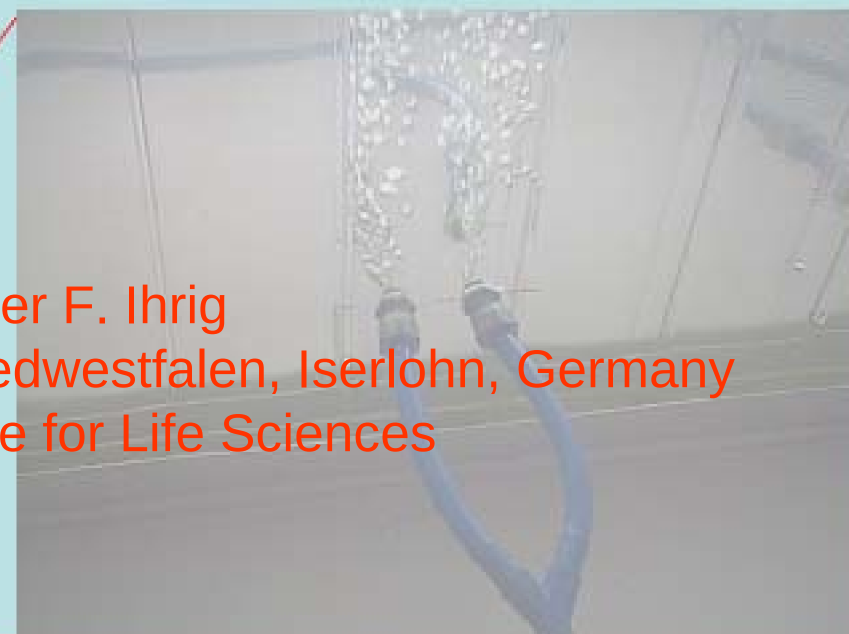
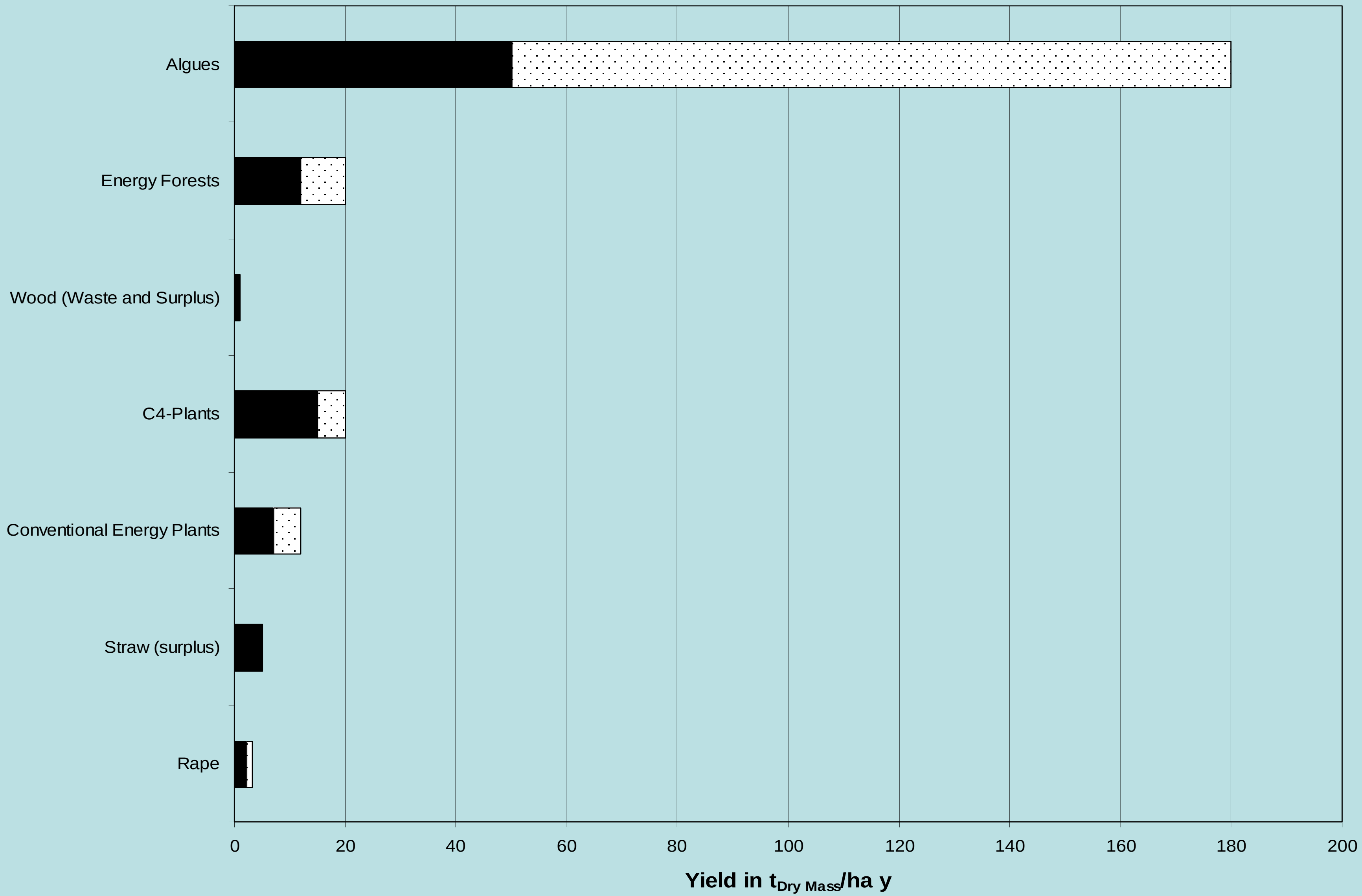
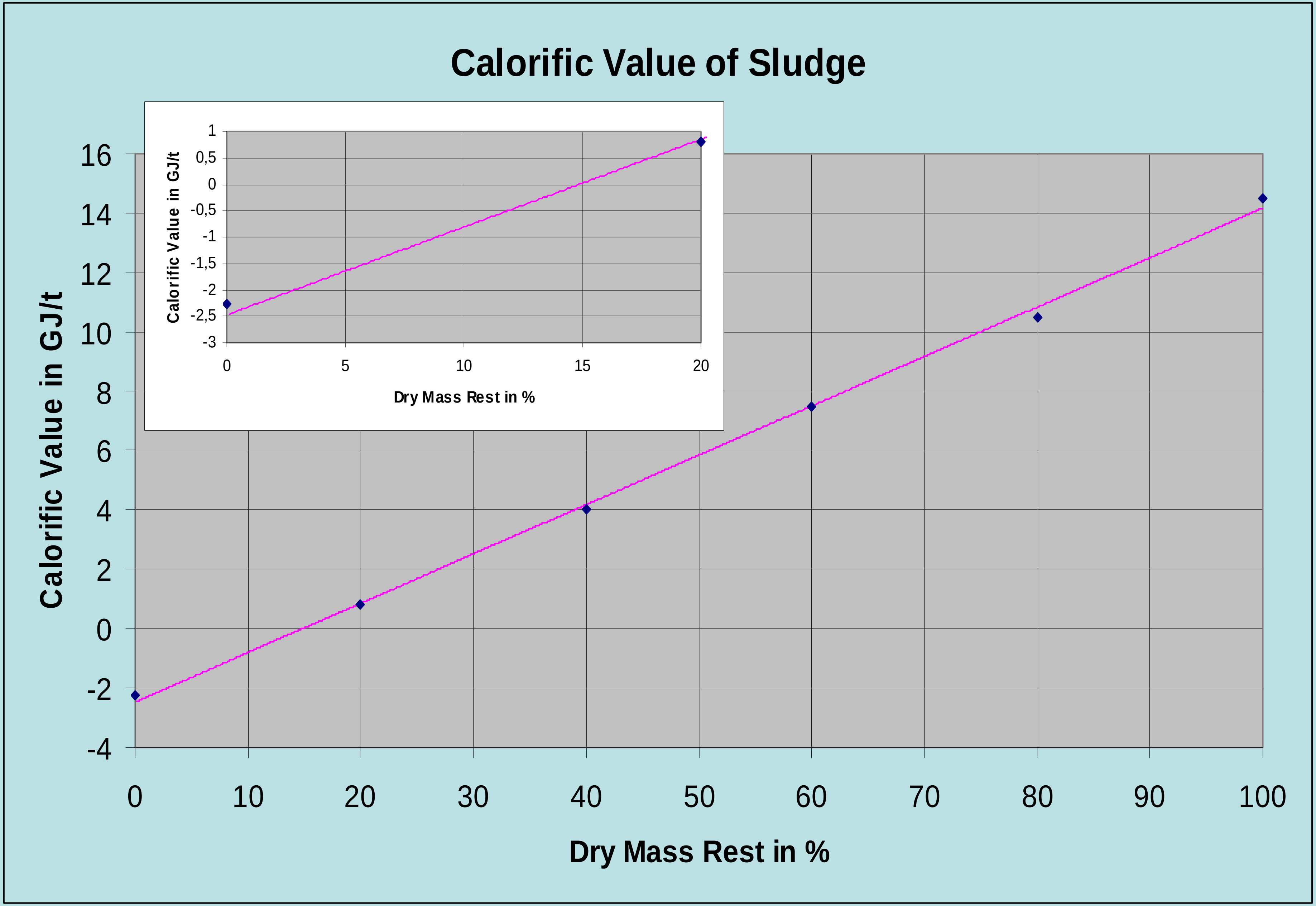
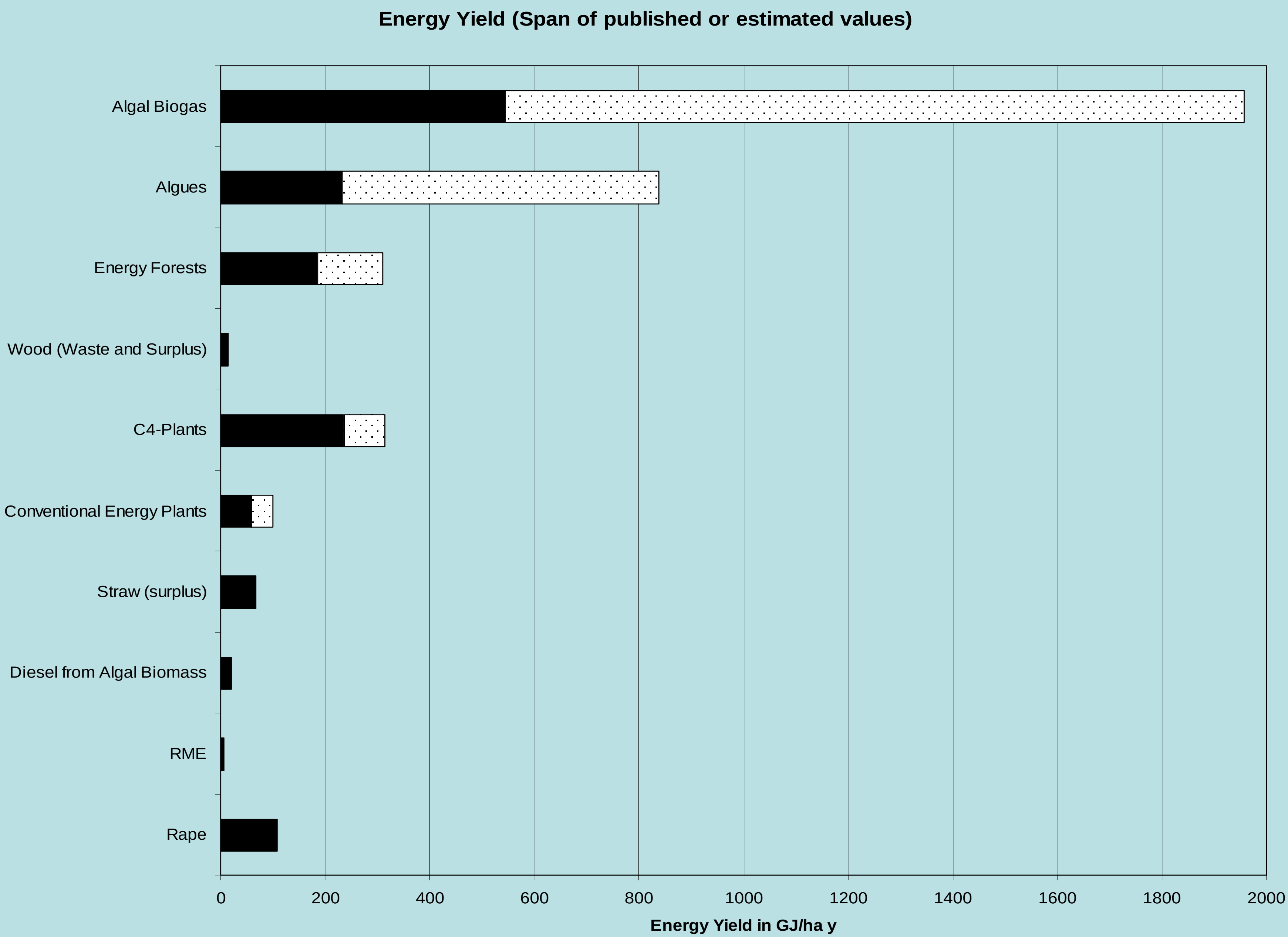
Prof. Dr. Dieter F. Ihrig
University of Applied Sciences Suedwestfalen, Iserlohn, Germany
Interdisciplinary Centre for Life Sciences

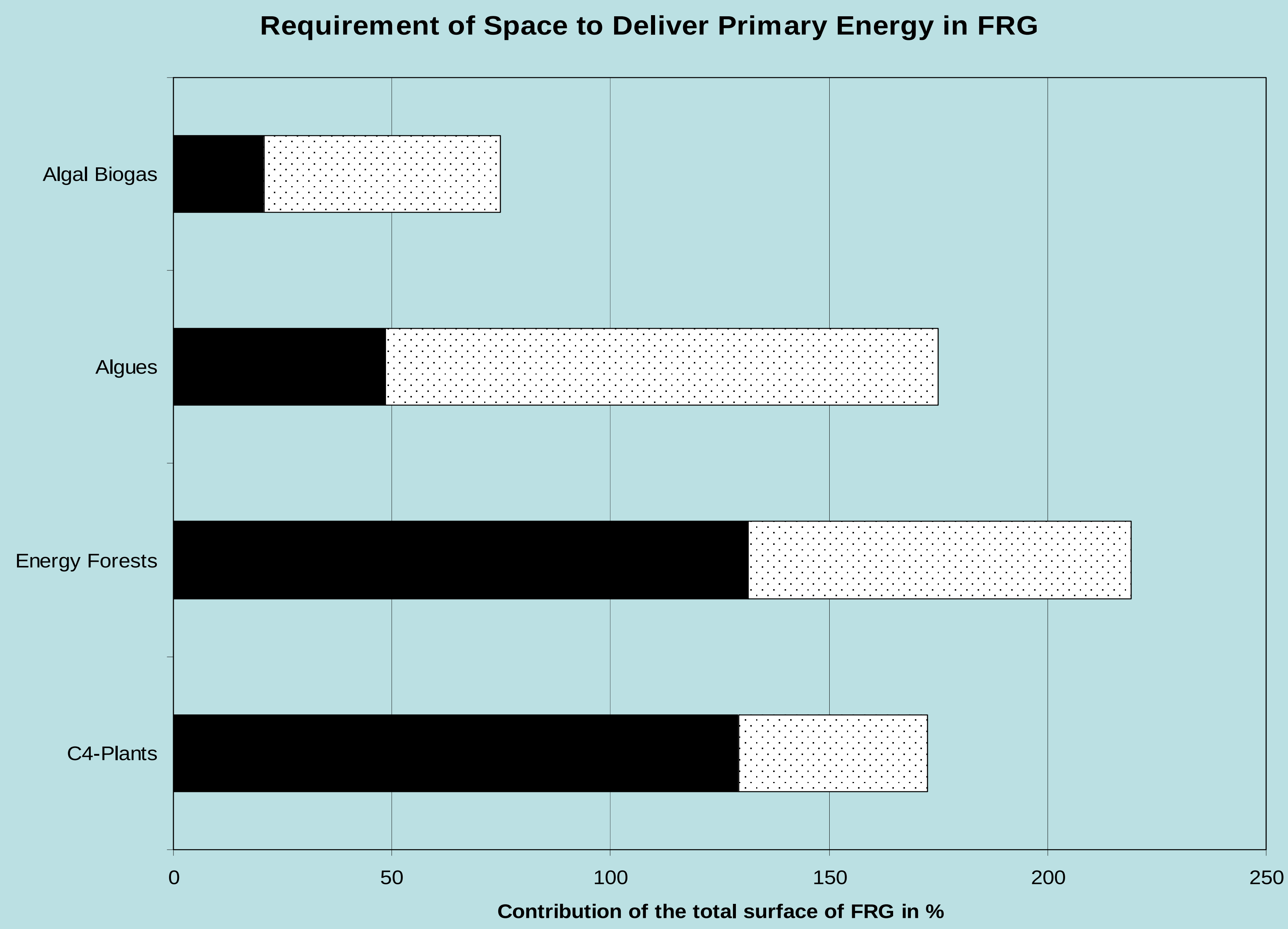


Yield of Biomass (Span of published values)

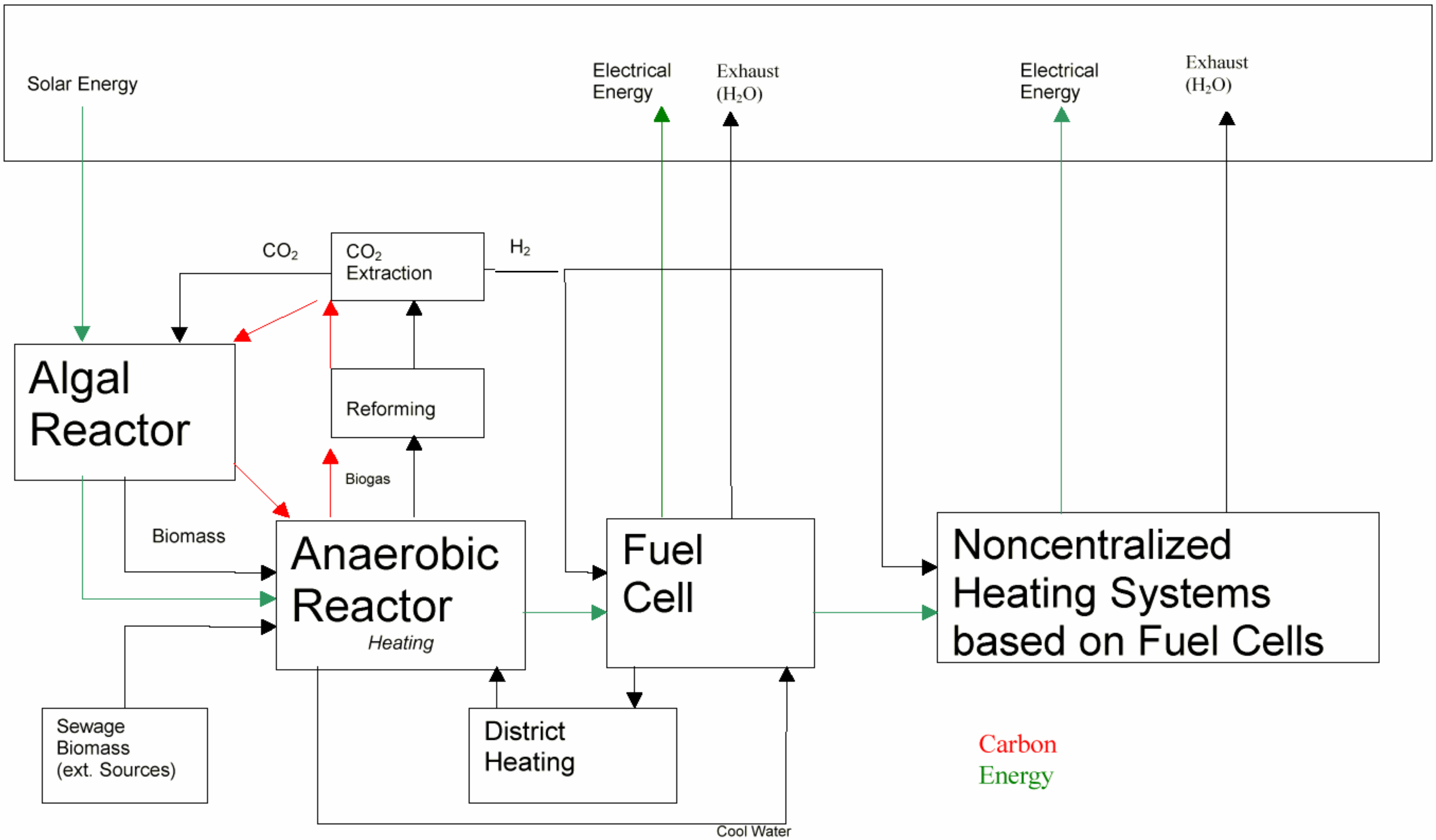



Calorific Value of Sludge
Calorific Value in GJ/t
Dry Mass Rest in %
16
14
12
10
8
6
4
2
0
-2
-4
0
10
20
30
40
50
60
70
80
90
100
1
0,5
0
-0,5
-1
-1,5
-2
-2,5
-3
5
15

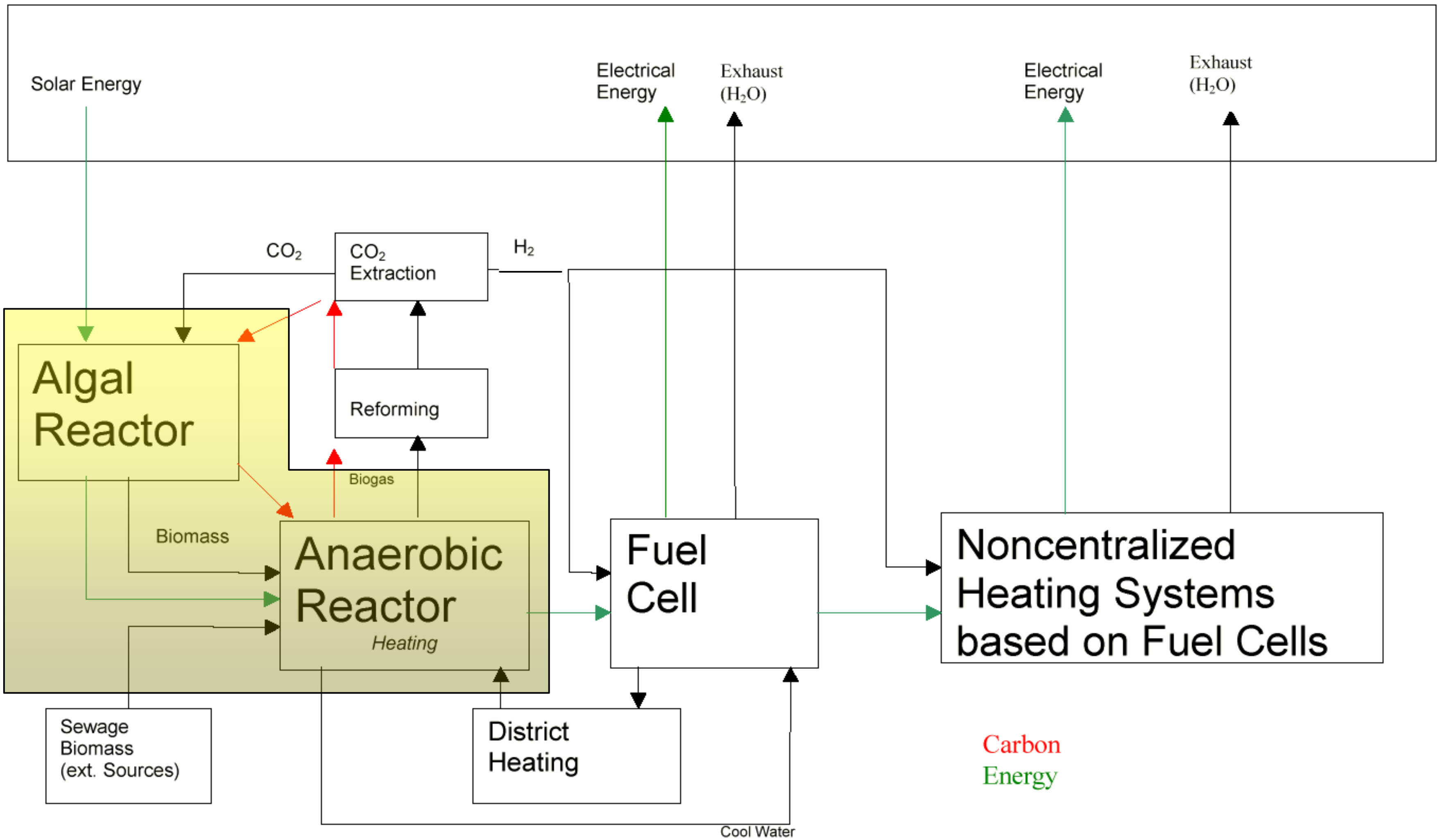

Energy Yield (Span of published or estimated values)
Algal Biogas
Algues
Energy Forests
Wood (Waste and Surplus)
C4-Plants
Conventional Energy Plants
Straw (surplus)
Diesel from Algal Biomass
RME
Rape
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Energy Yield in GJ/ha y


Requirement of Space to Deliver Primary Energy in FRG
Algal Biogas
Algues
Energy Forests
C4-Plants
0
50
100
150
200
250
Contribution of the total surface of FRG in %

Biological Solar Energy Generator

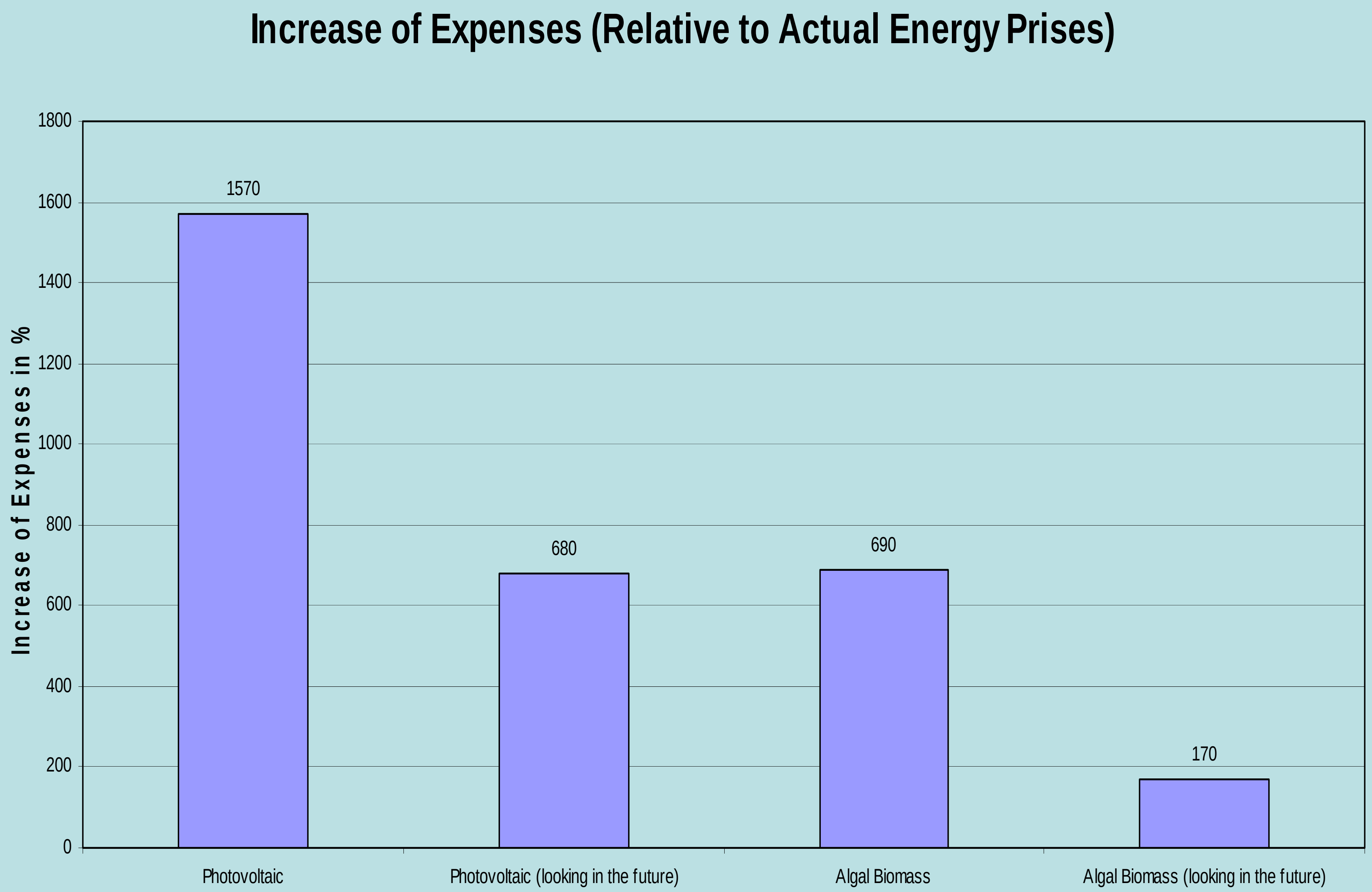


Biological Solar Energy Generator



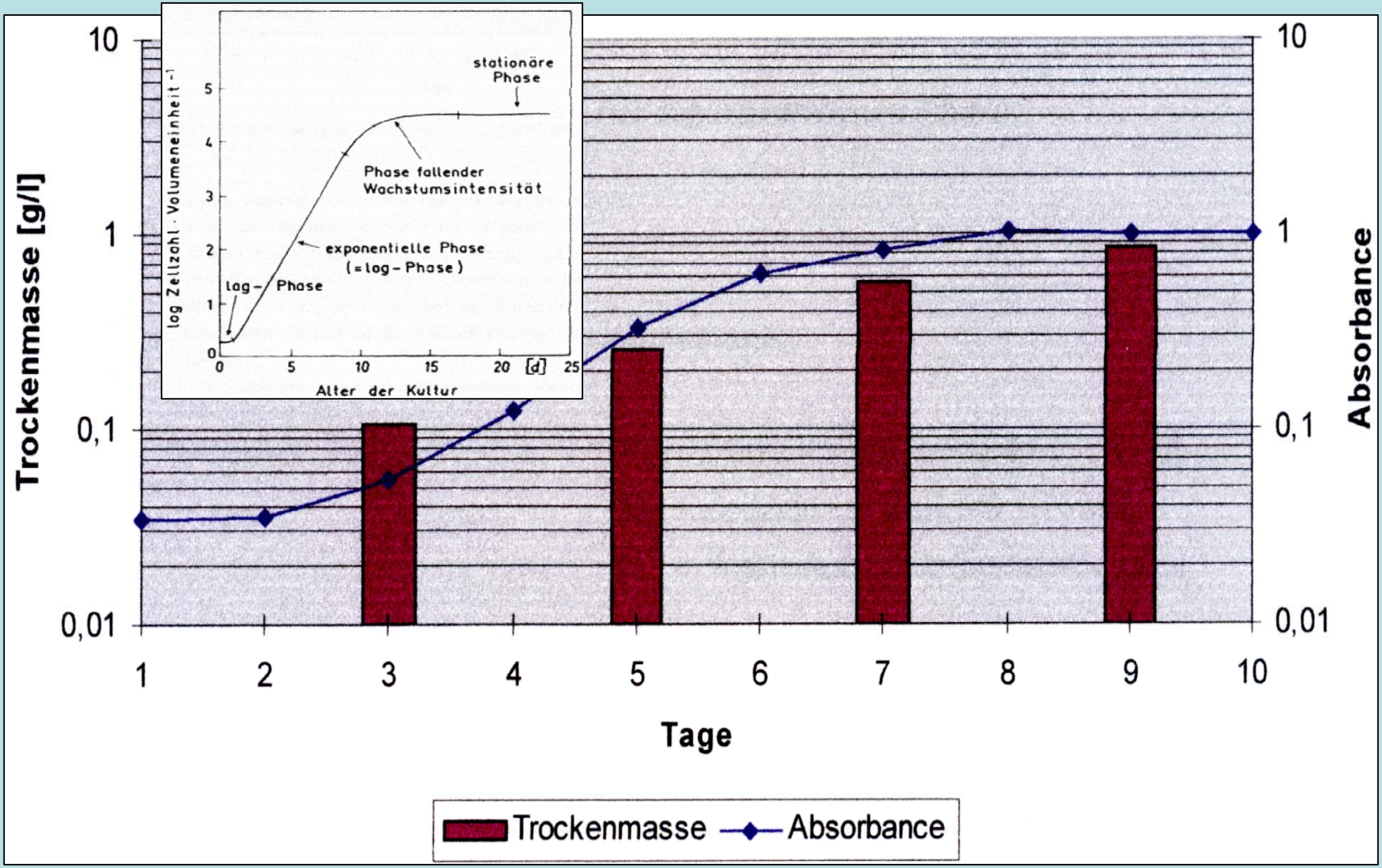
Process Simulation

Loss of Carbon					Compensation:	Slurry from cows	
CO_2-loss via exhaust:	2.416.574	m3/a =	1.208,29	t/a	Content of Carbon:	33,6	%
CH_4-delivery:	3.844.750	m3/a =	1.922,38	t/a	Moisture:	70	%
Sum:			3.130,66	t/a	Mass:	31.058,2	t/a
					after adjusting process moisture:	39.931,9	t/a
					Calorific value:	6,99E+13	J/a
Process data							
Moisture:	90	%					
Mass flow at process moisture:	134.486,3	t/a					
Mass flow at 70 % moisture:	104.600,5	t/a					
Energy harvest						Power	
Electrical:	5,60E+13	J/a	1,55E+04	MWh/a		1.775,0	kW
Thermal:	1,29E+13	J/a	3,58E+03	MWh/a		409,1	kW
Methane:	1,38E+14	J/a	3,83E+04	MWh/a		4.376,8	kW
Sum:	2,07E+14	J/a	5,75E+04	MWh/a		6.560,9	kW
Net yield:	1,37E+14	J/a	3,81E+04	MWh/a		4.345,0	kW
Requirement of floorspace					**Investment**		
Algal reactors (ponds):	590.965	m2			Algal reactors (ponds):	4.834.500	€
Anaerobic reactor:	20.000	m2			Anaerobic reactor:	51.129.200	€
Local power plant / Gas separation:	2.212	m2			Local power plant / Gas separation:	4.329.000	€
Sum:	613.177	m2			Sum:	60.292.700	€
Specific floorspace:	2,96	m2/(GJ/a)			**End energy supply (1998)**		
Specific energy harvest:	3.374,3	GJ/ha a			Base: consumption	only households	total
Net specific energy harvest:	2.234,7	GJ/ha a			Citizens	6.041	1.790
					Households	2.762	818

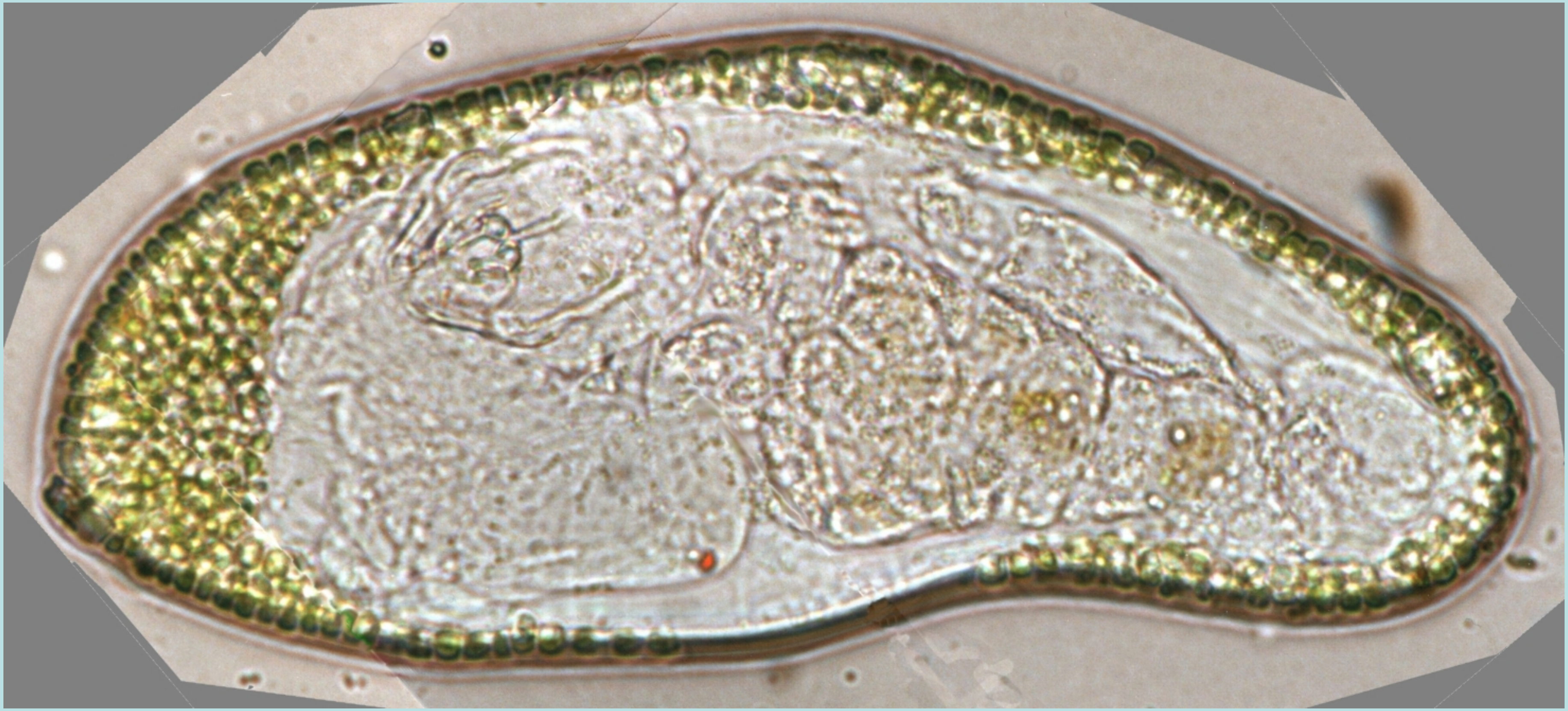

Increase of Expenses (Relative to Actual Energy Prises)
Increase of Expenses in %
1800
1600
1400
1200
1000
800
600
400
200
0
1570
680
690
170
Photovoltaic
Photovoltaic (looking in the future)
Algal Biomass
Algal Biomass (looking in the future)

Micro-algal reactor

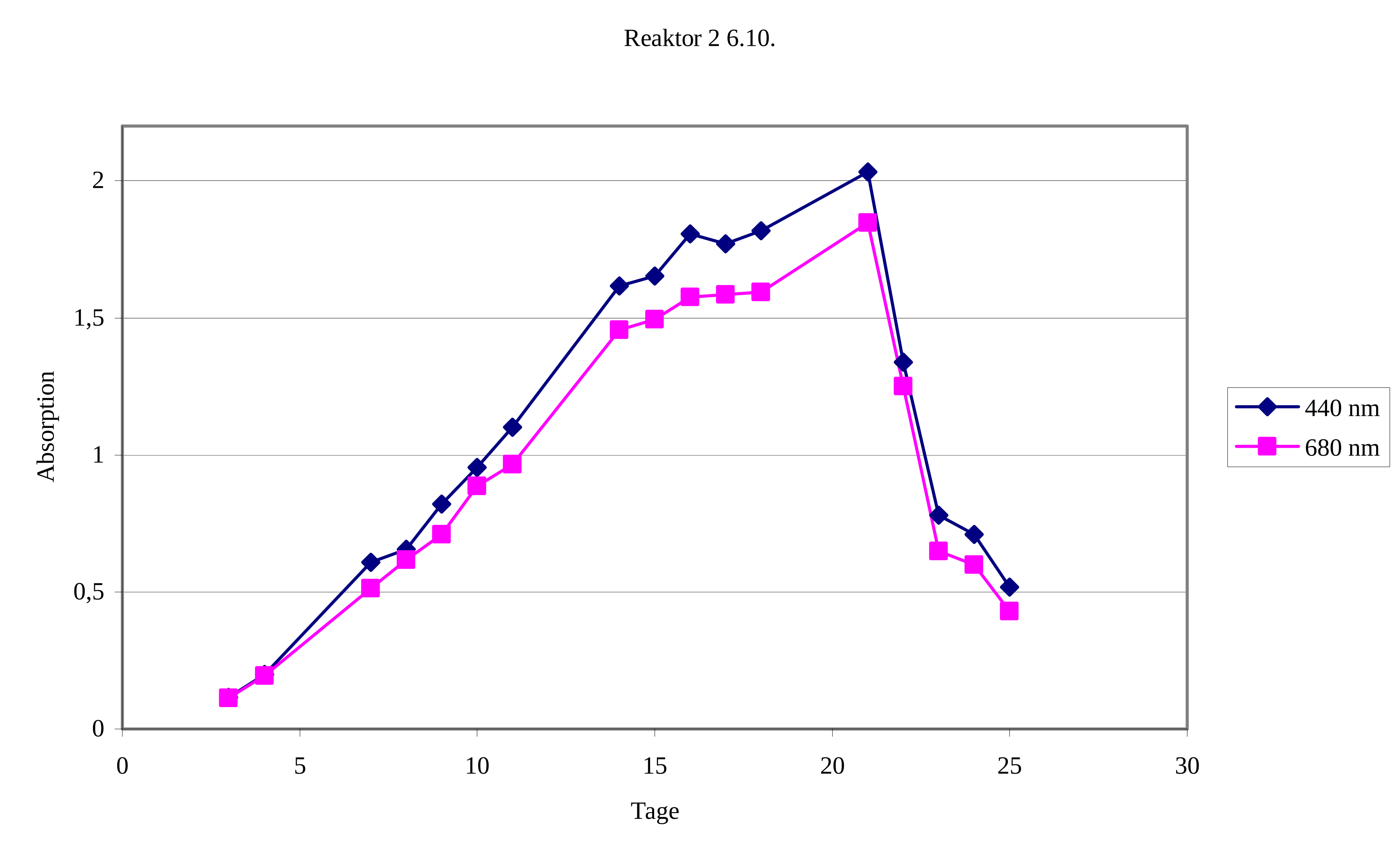
Win Algal Biomass



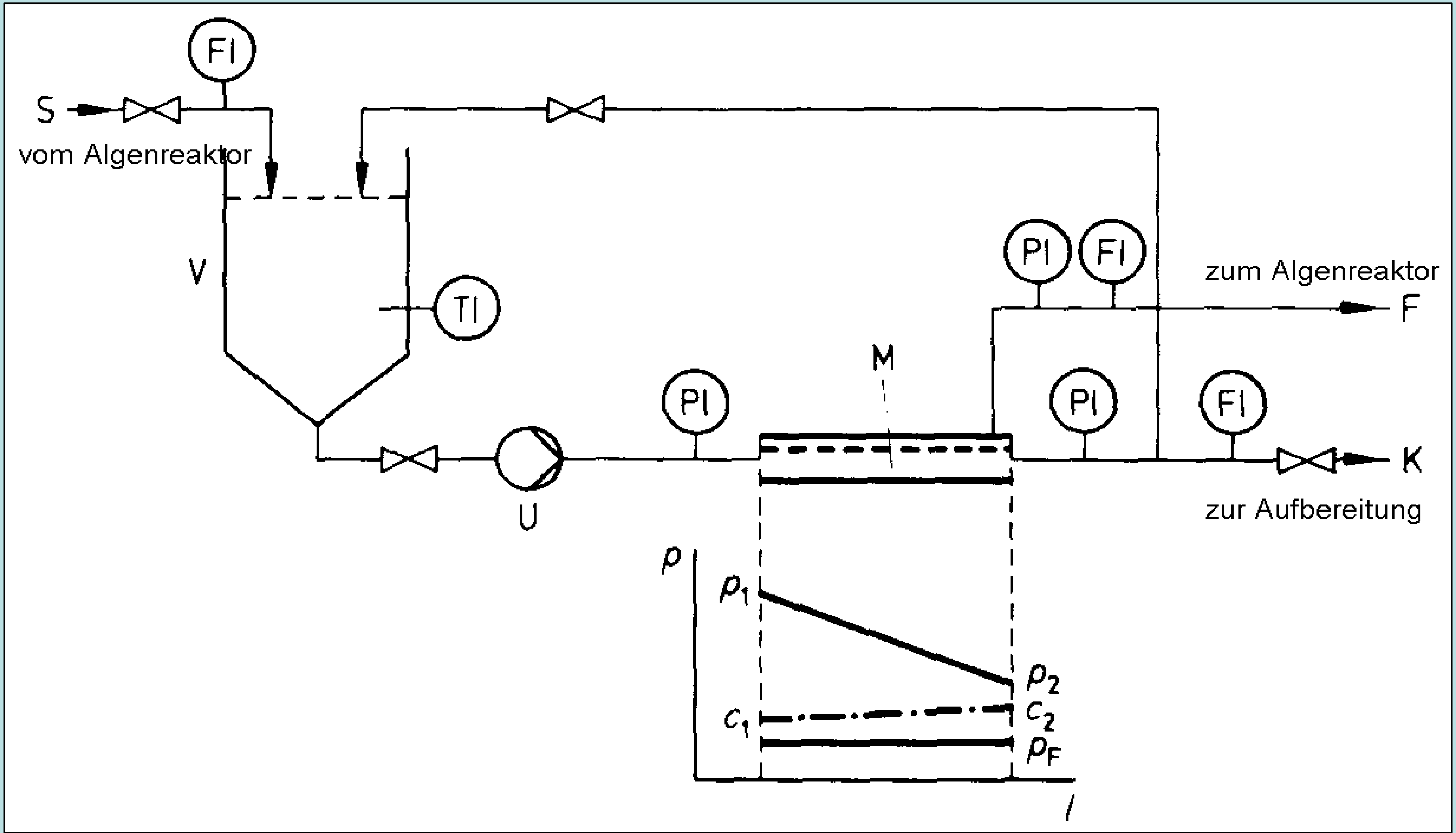
Difficulties



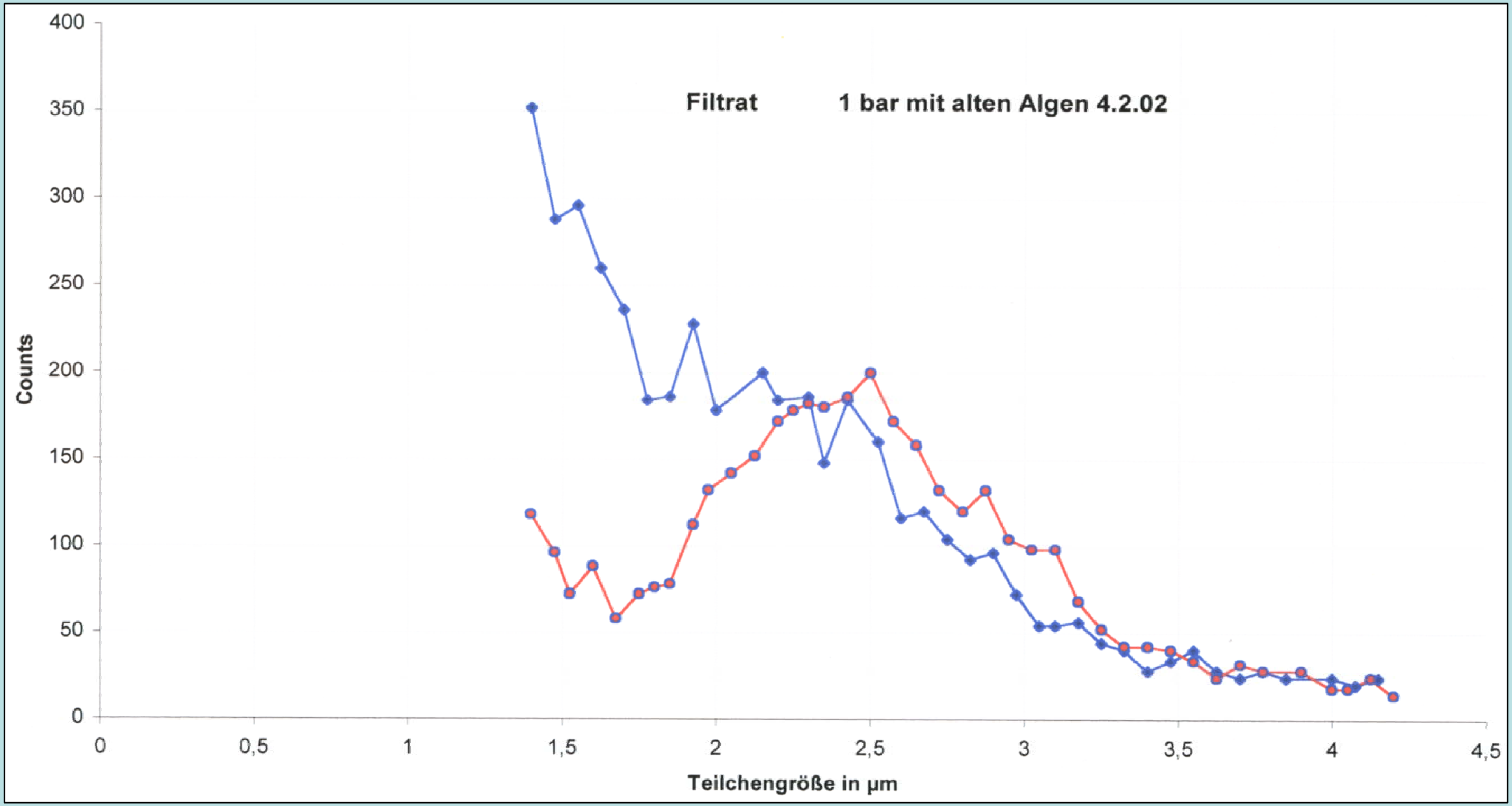
Difficulties



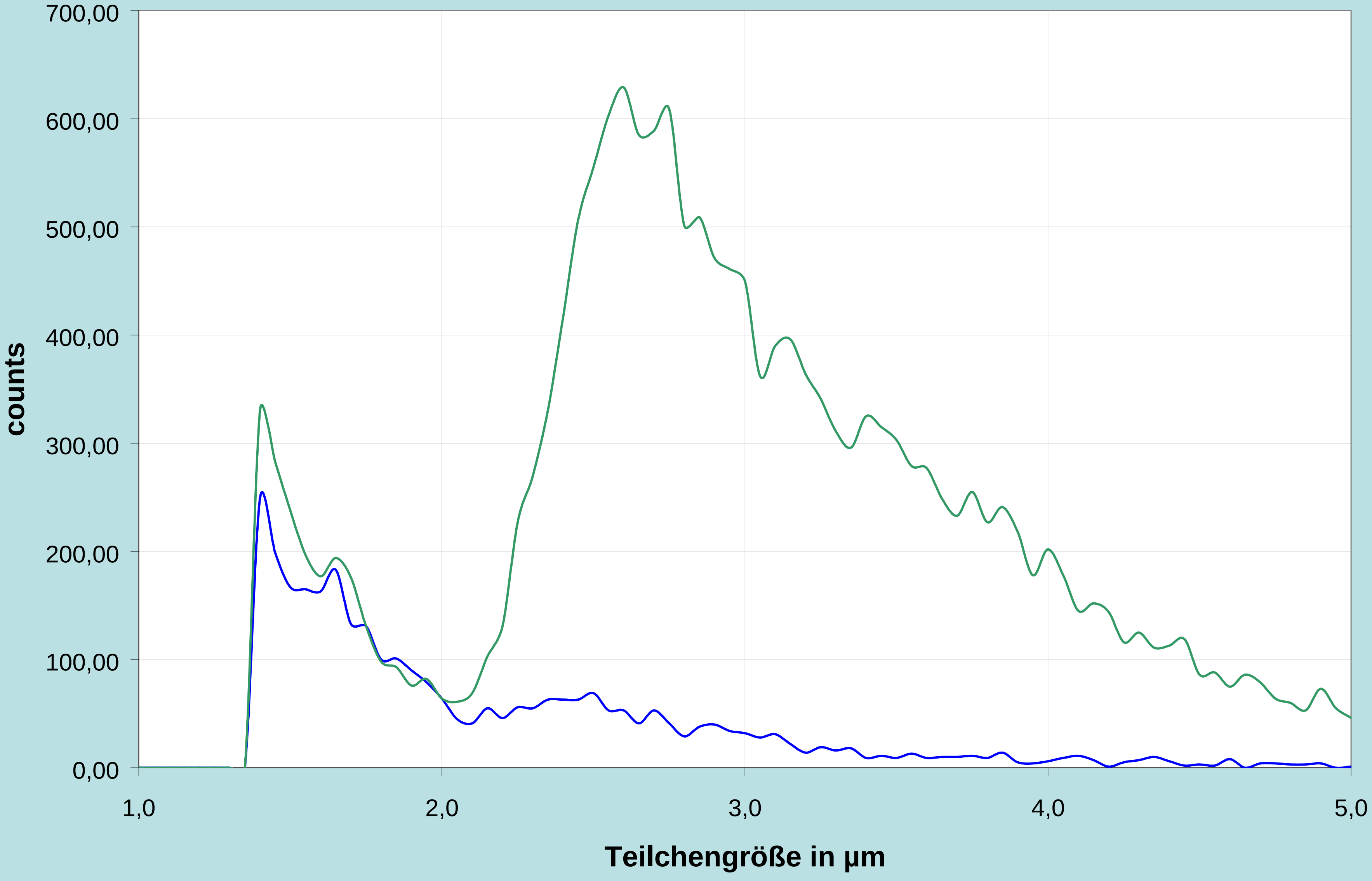
Harvesting Micro-Algal Biomass



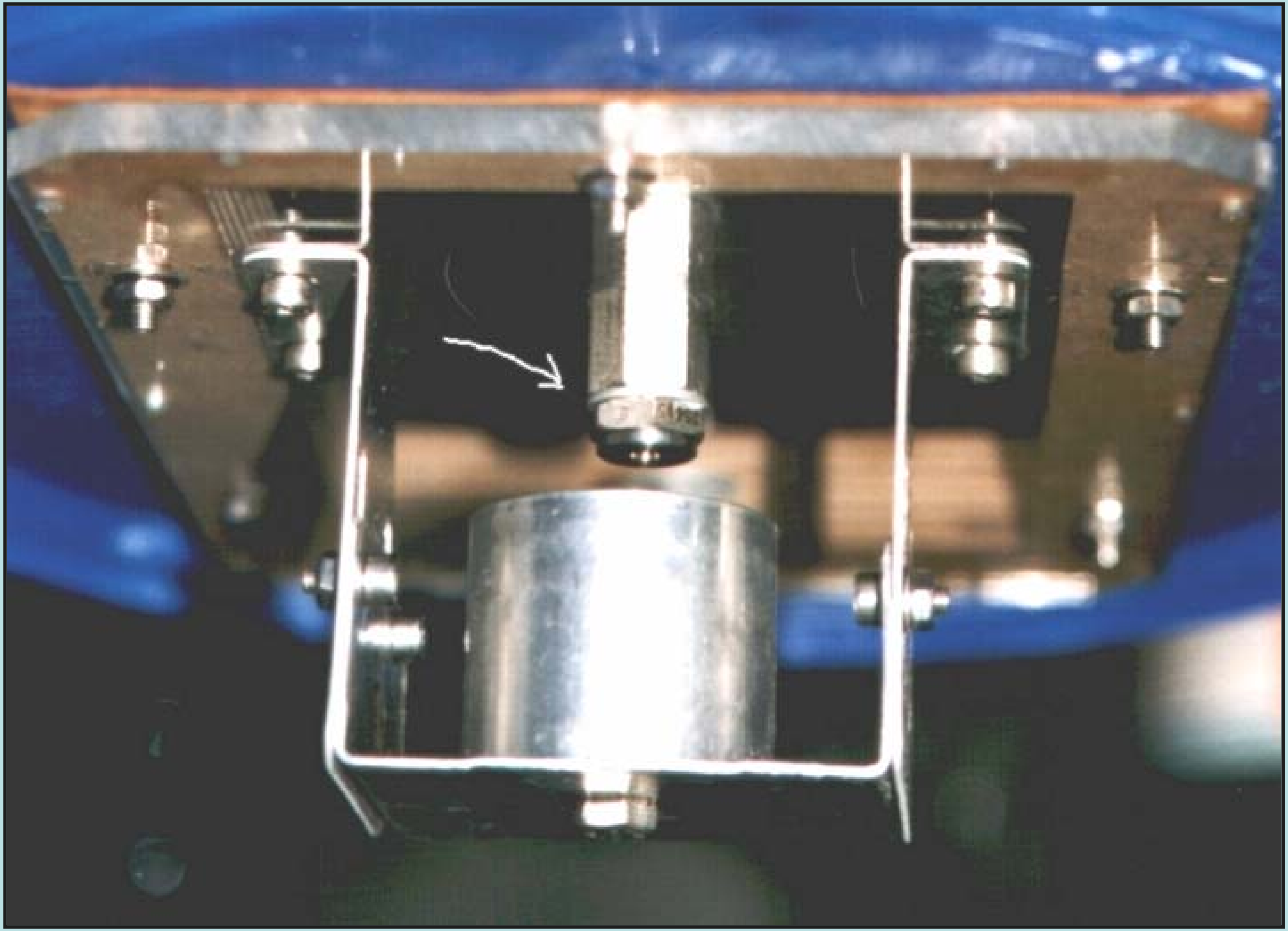
Harvesting Micro-Algal Biomass



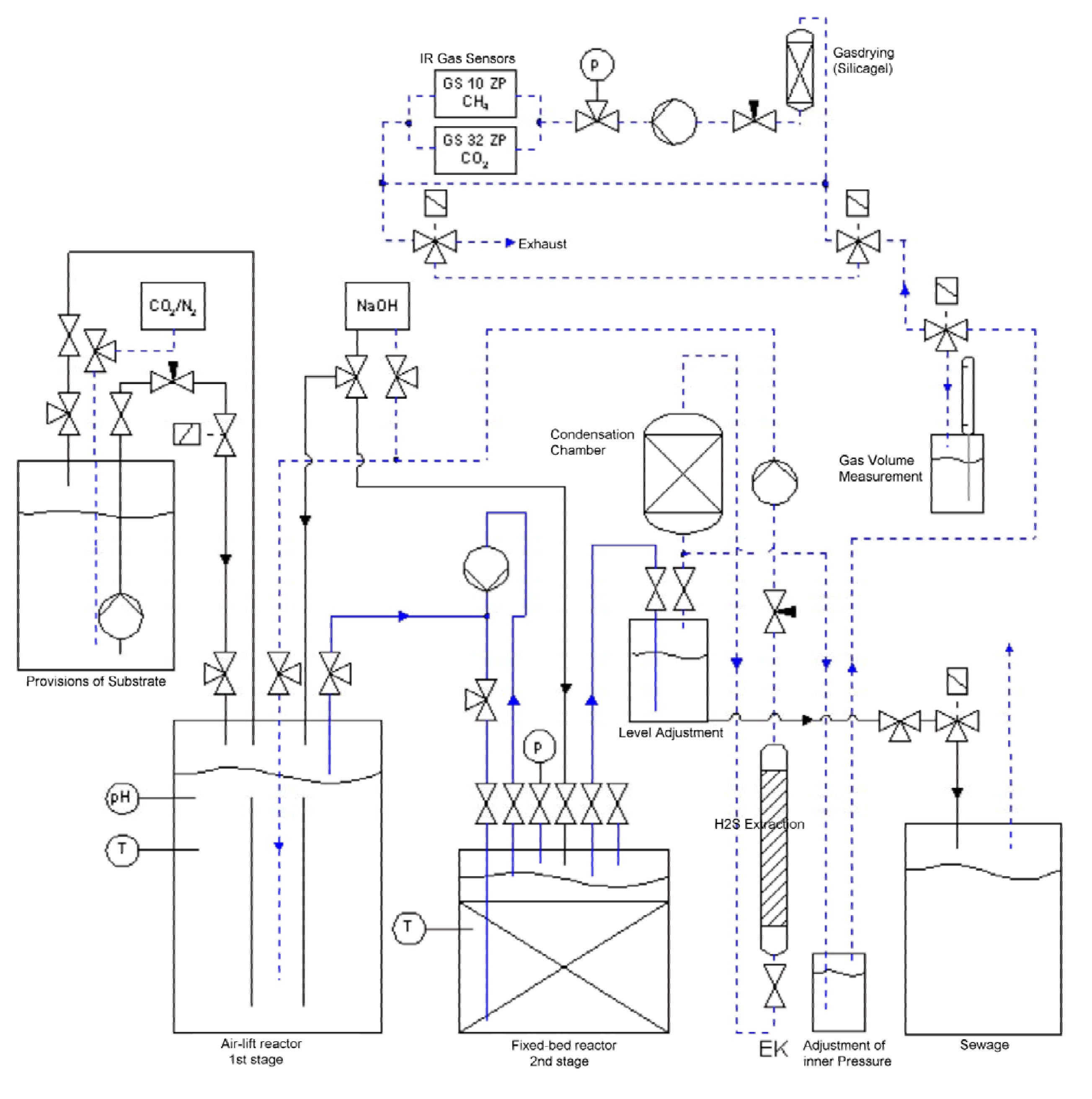
Harvesting Micro-Algal Biomass



Treatment of Micro-Algal Biomass

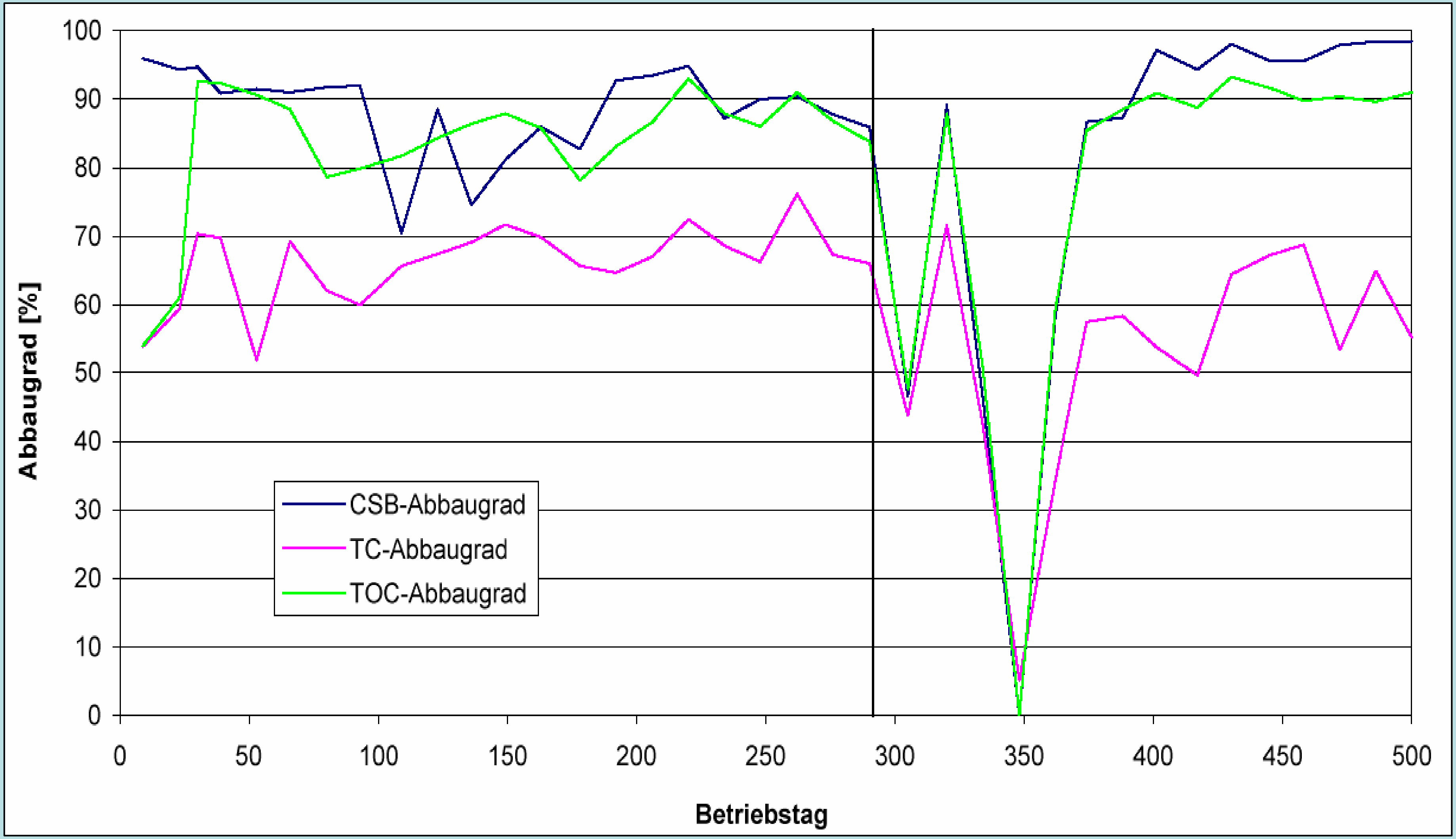


Anaerobic reactor


IR Gas Sensors
GS 10 ZP
CH_4
GS 32 ZP
CO_2
P
Gasdrying
(Silicagel)
Exhaust
CO_2/N_2
NaOH
Condensation
Chamber
Gas Volume
Measurement
Provisions of Substrate
Level Adjustment
P
H2S Extraction
pH
T
T
Air-lift reactor
1st stage
Fixed-bed reactor
2nd stage
EK
Adjustment of
inner Pressure
Sewage

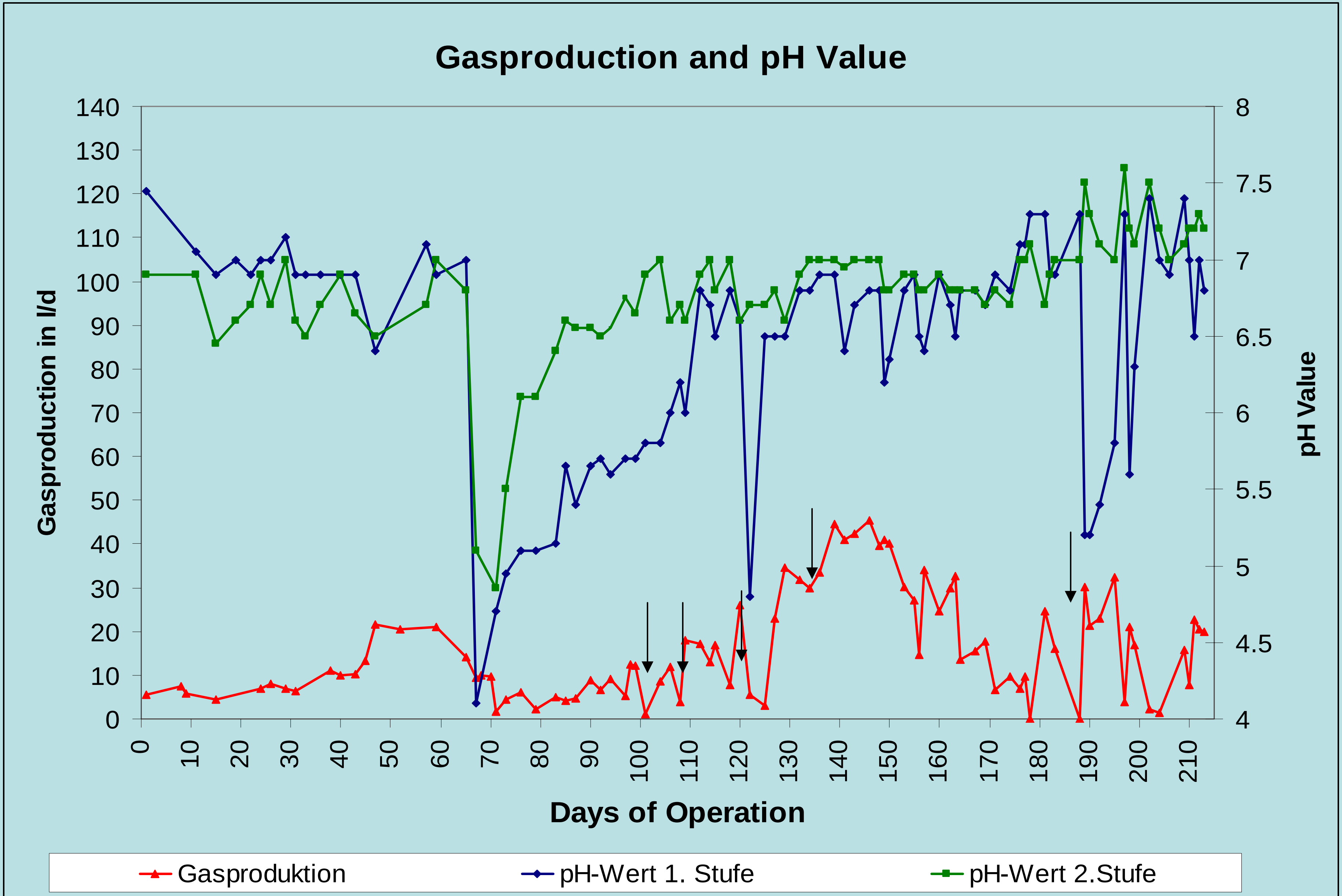
Anaerobic Process

Fixed bed | fluidized bed

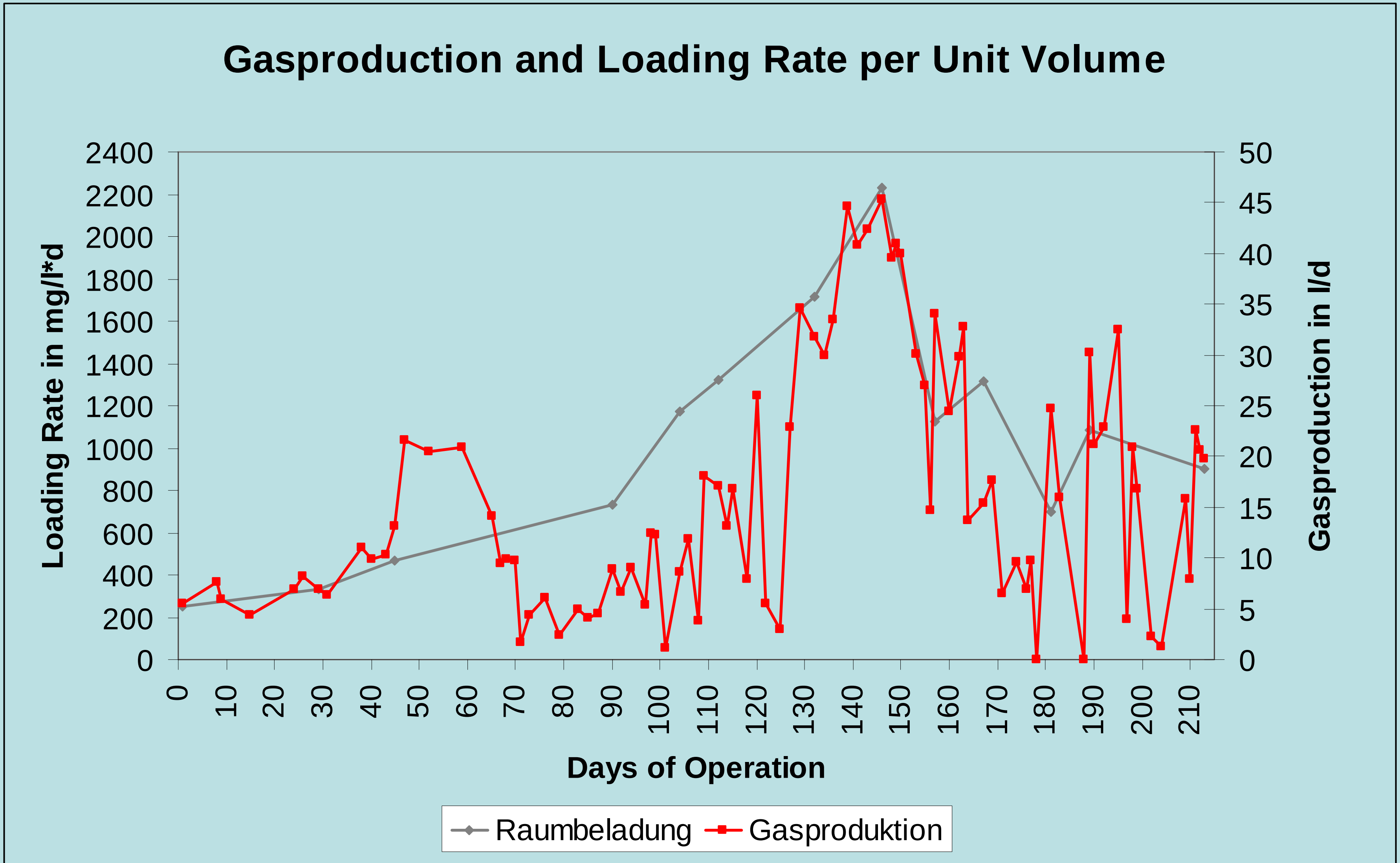


mesophilic/mesophilic | thermophilic/mesophilic

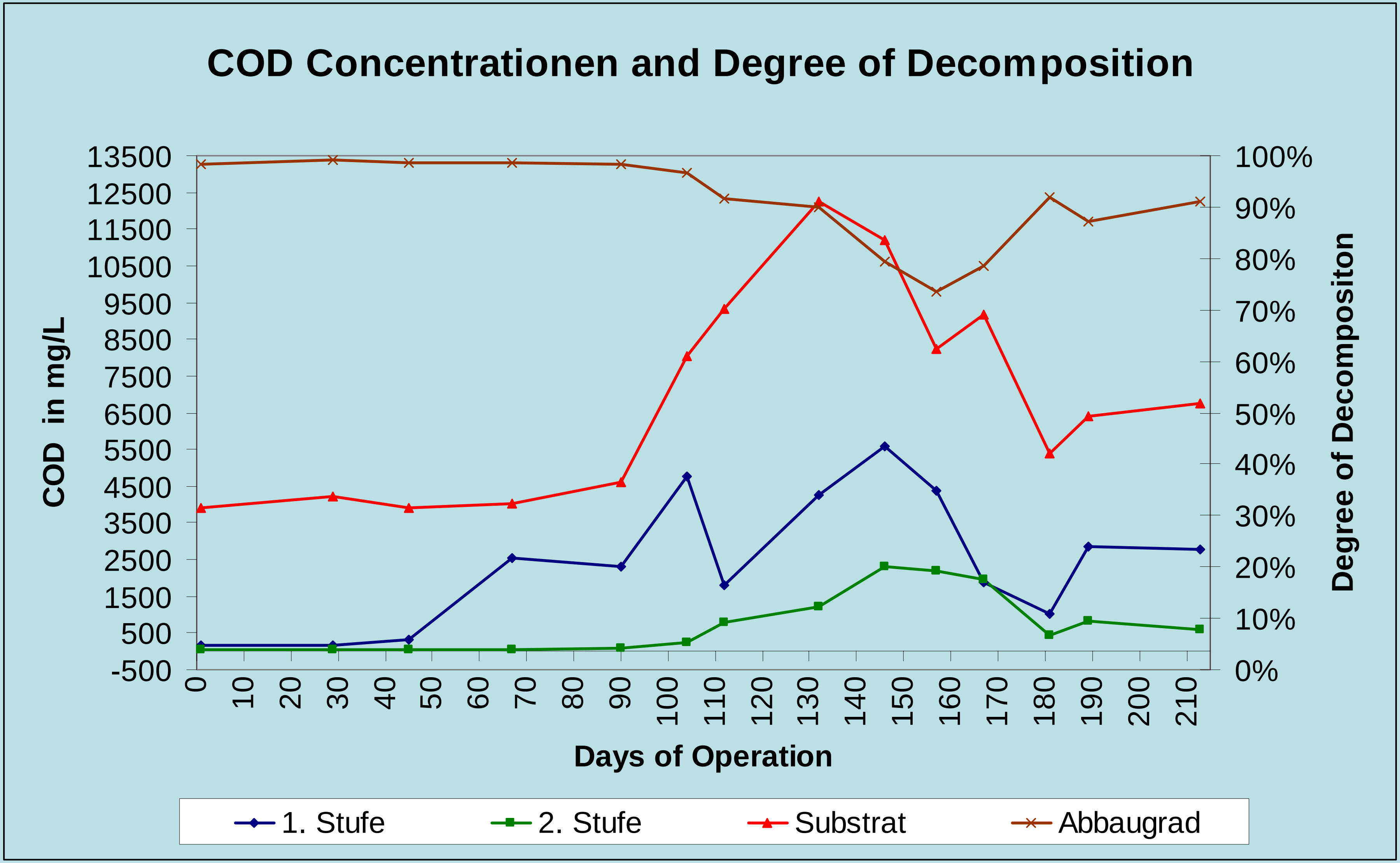
Anaerobic Process using Micro-Algal Biomass



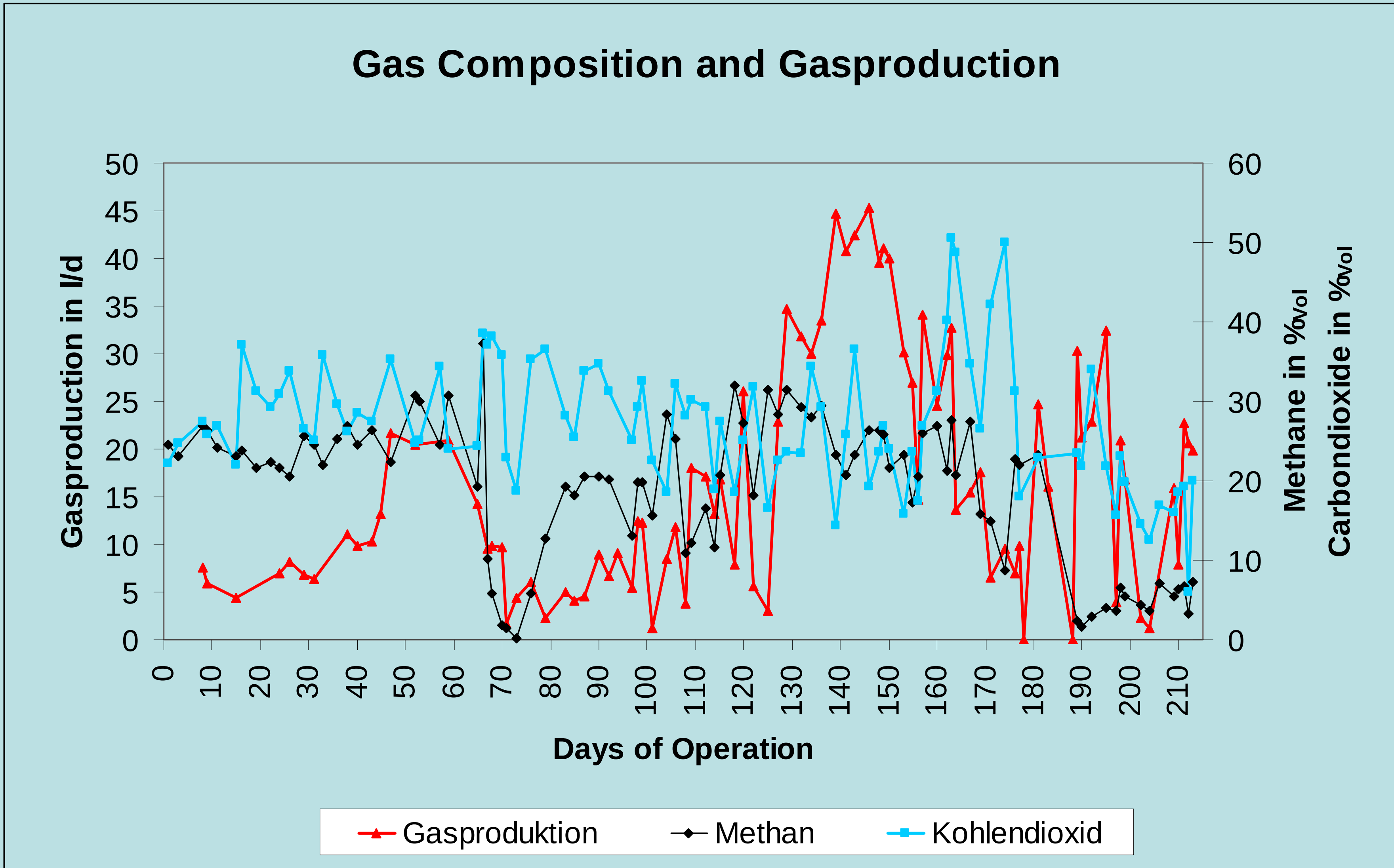
Anaerobic Process using Micro-Algal Biomass



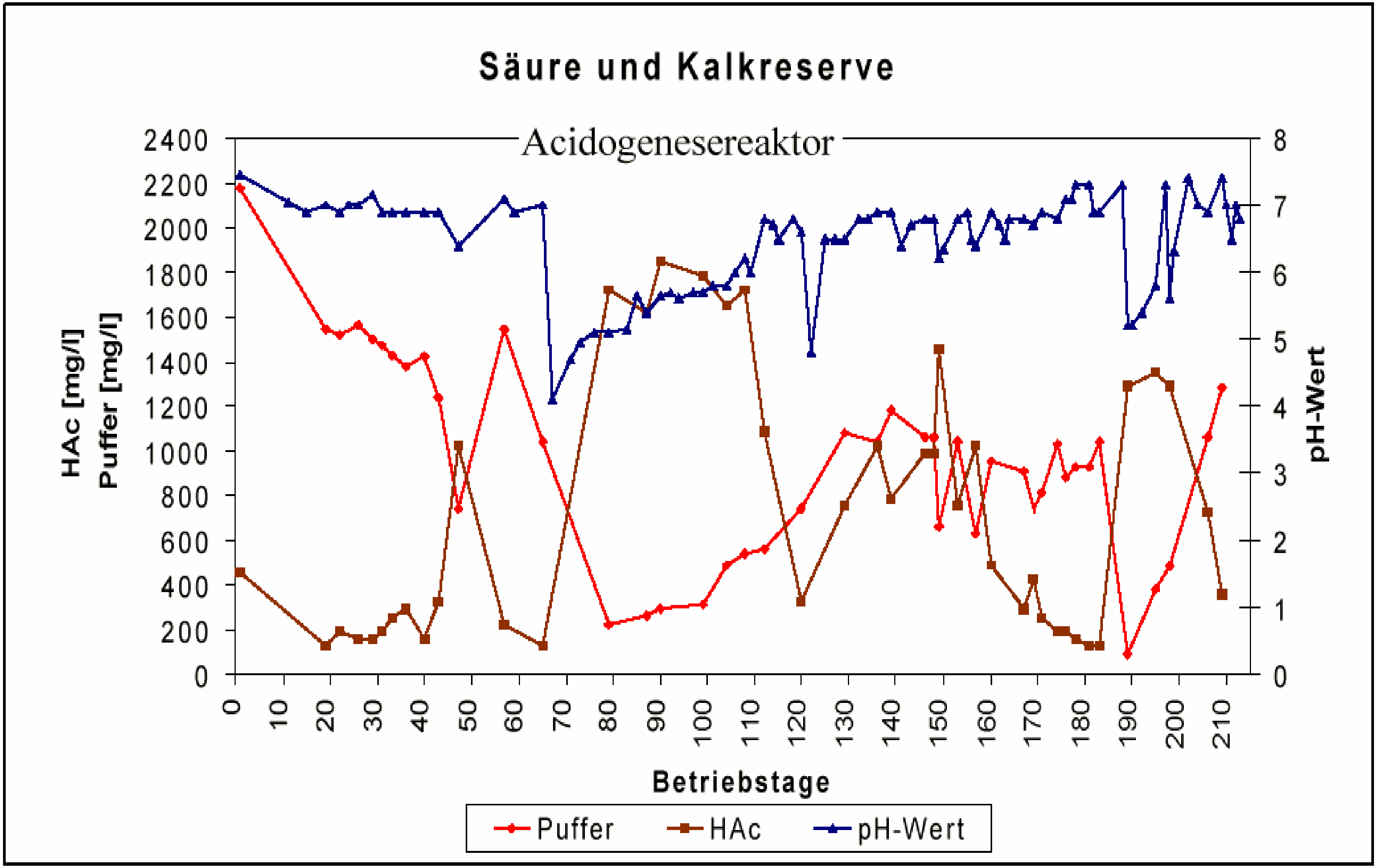
Anaerobic Process using Micro-Algal Biomass



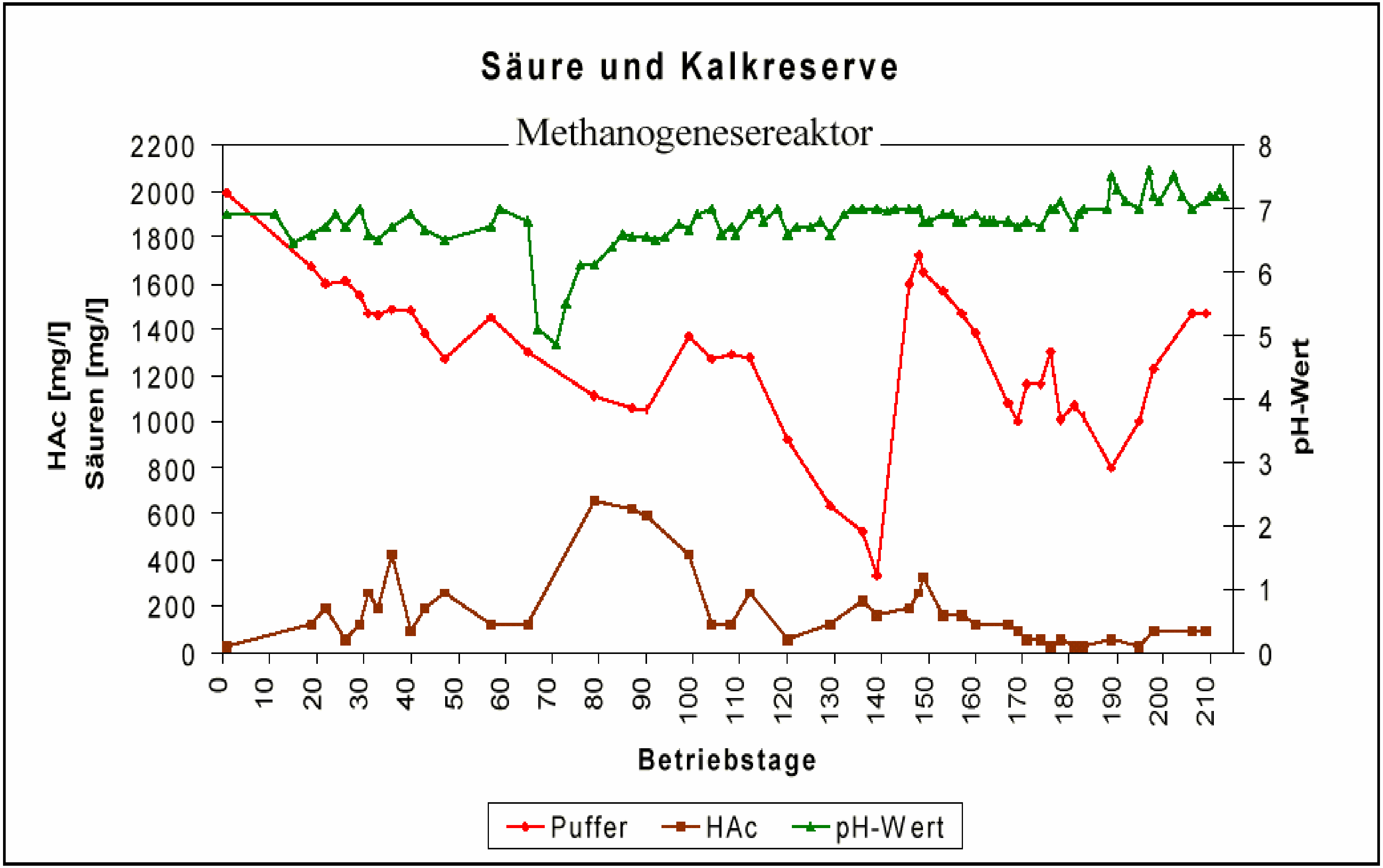
Anaerobic Process using Micro-Algal Biomass



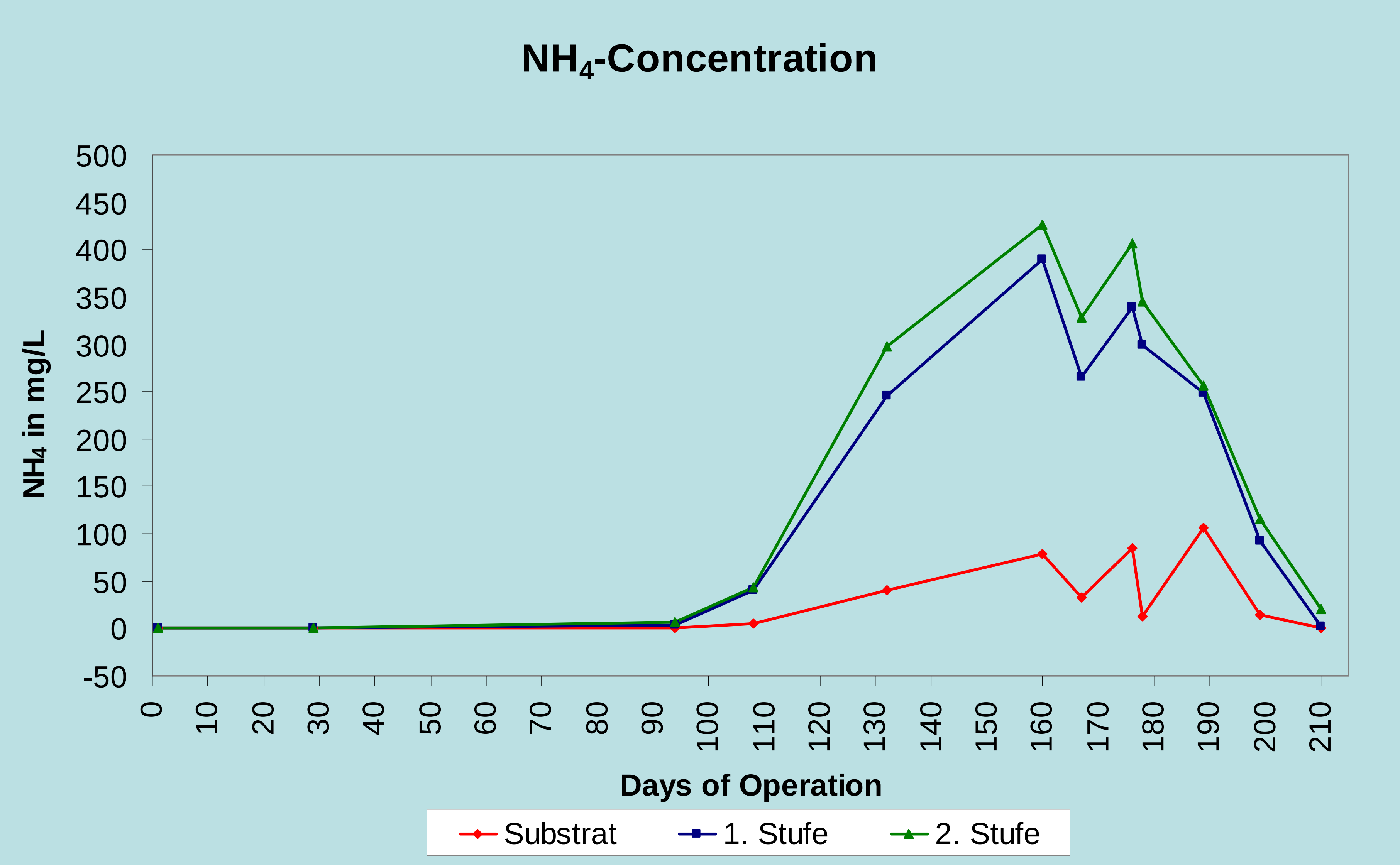
Anaerobic Process using Micro-Algal Biomass

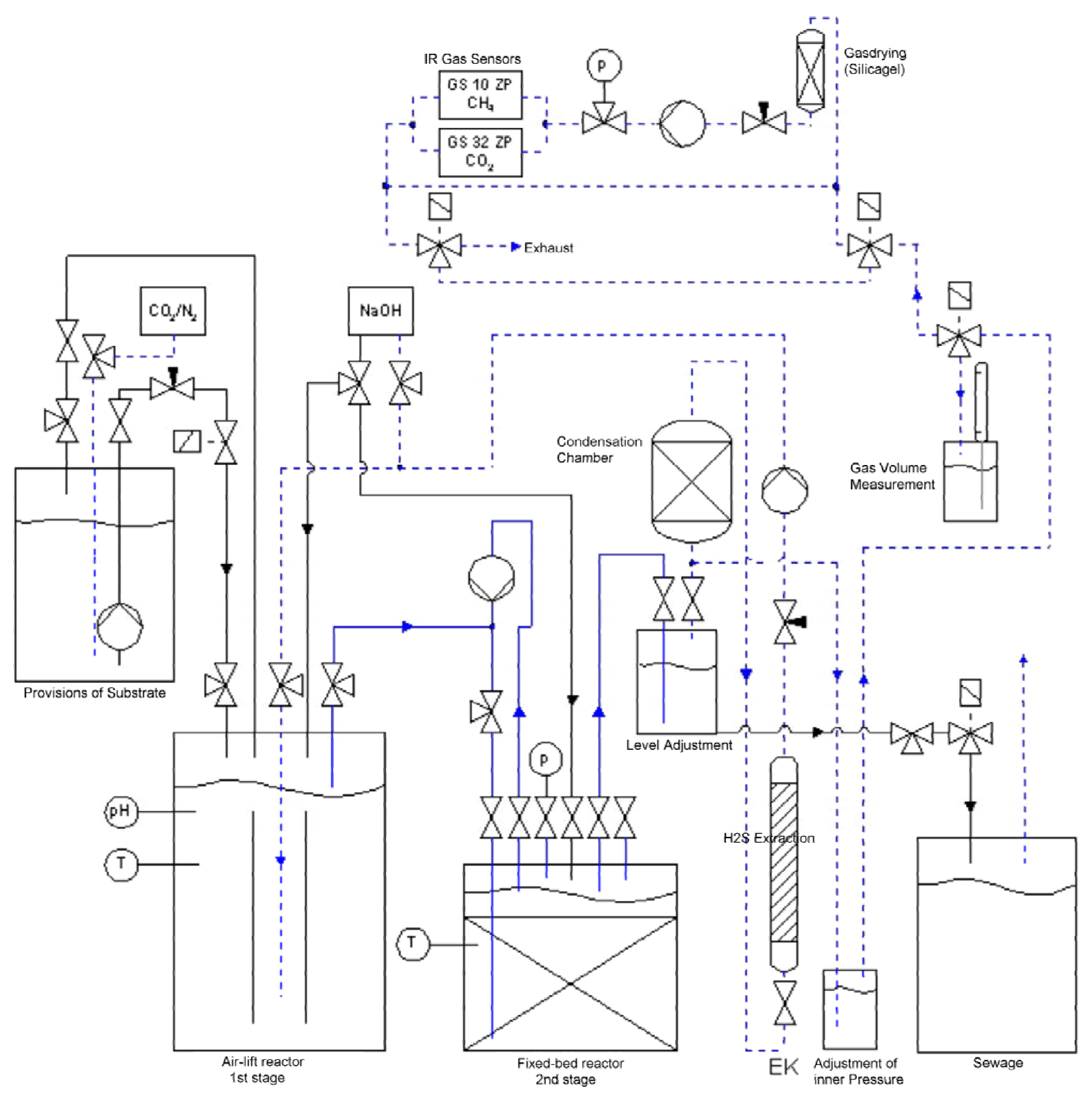


Anaerobprozess mit Algenbiomasse

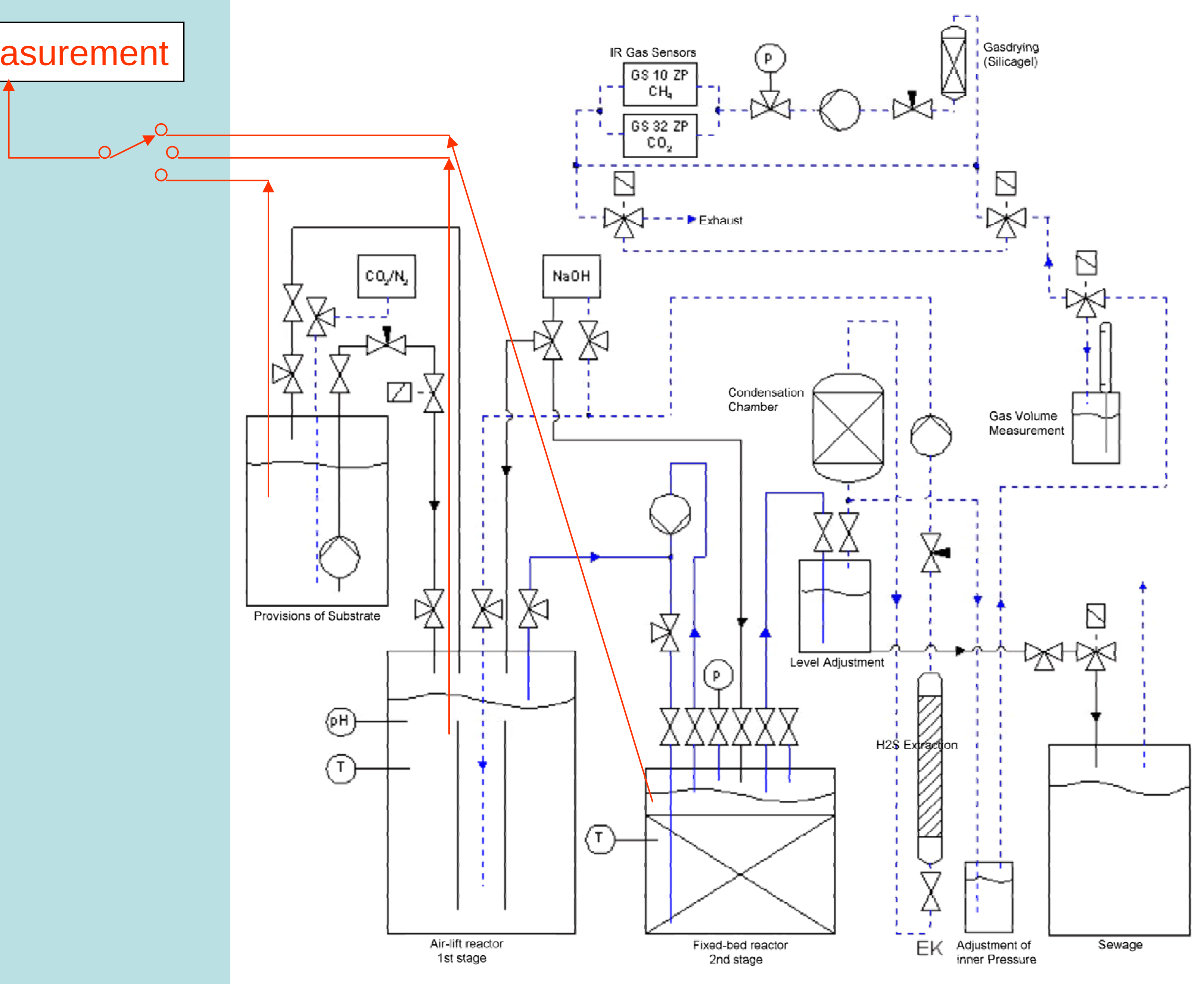


Anaerobic Process using Micro-Algal Biomass

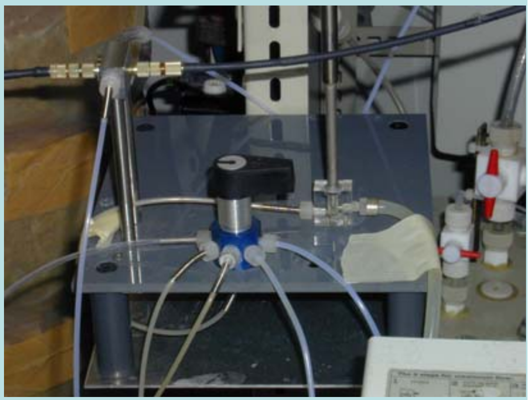


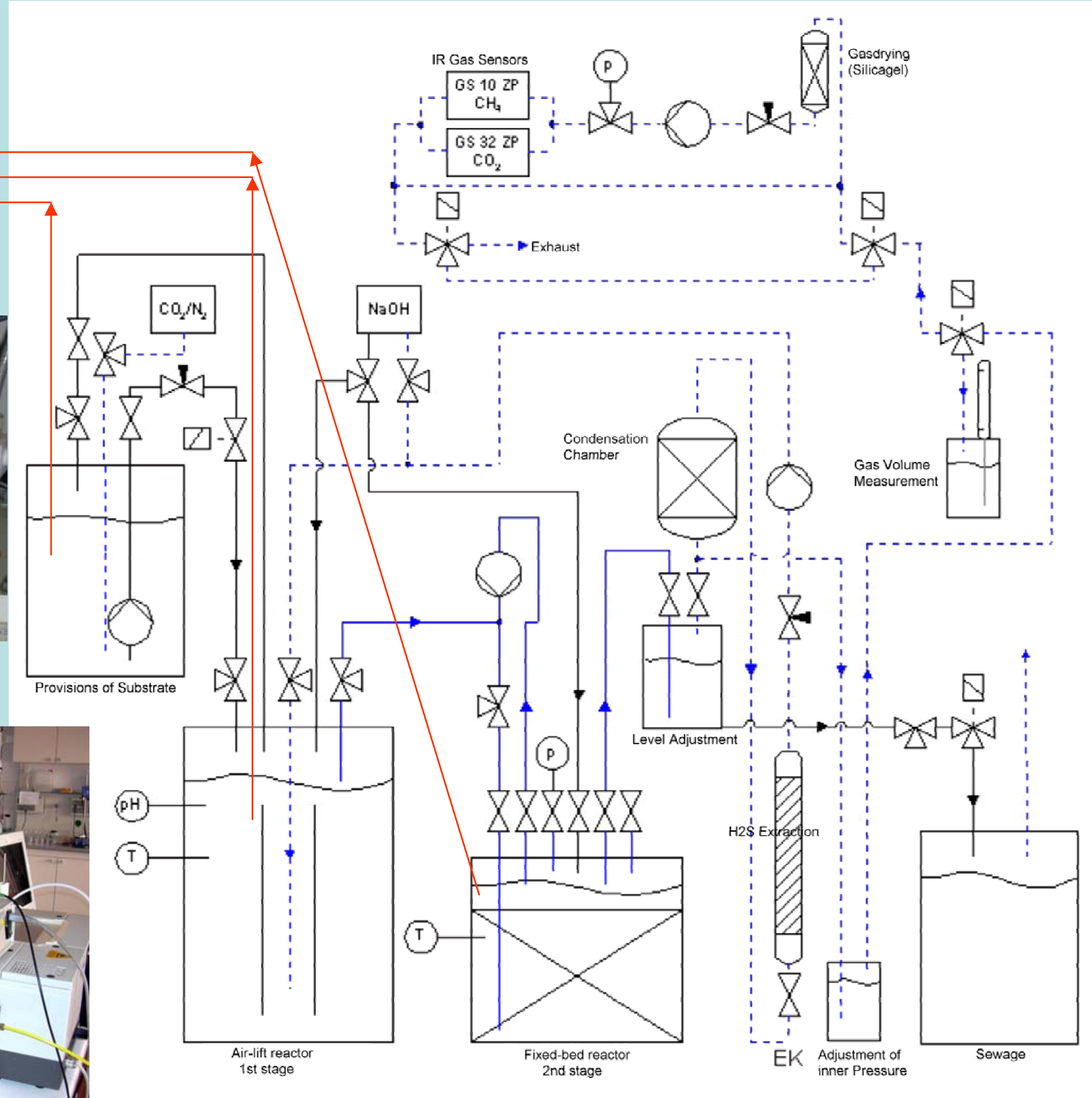

IR Gas Sensors
GS 10 ZP CH_4
GS 32 ZP CO_2
P
Gasdrying (Silicagel)
Exhaust
CO_2/N_2
NaOH
Condensation Chamber
Gas Volume Measurement
Provisions of Substrate
Level Adjustment
P
pH
T
T
H2S Extraction
Air-lift reactor 1st stage
Fixed-bed reactor 2nd stage
EK
Adjustment of inner Pressure
Sewage

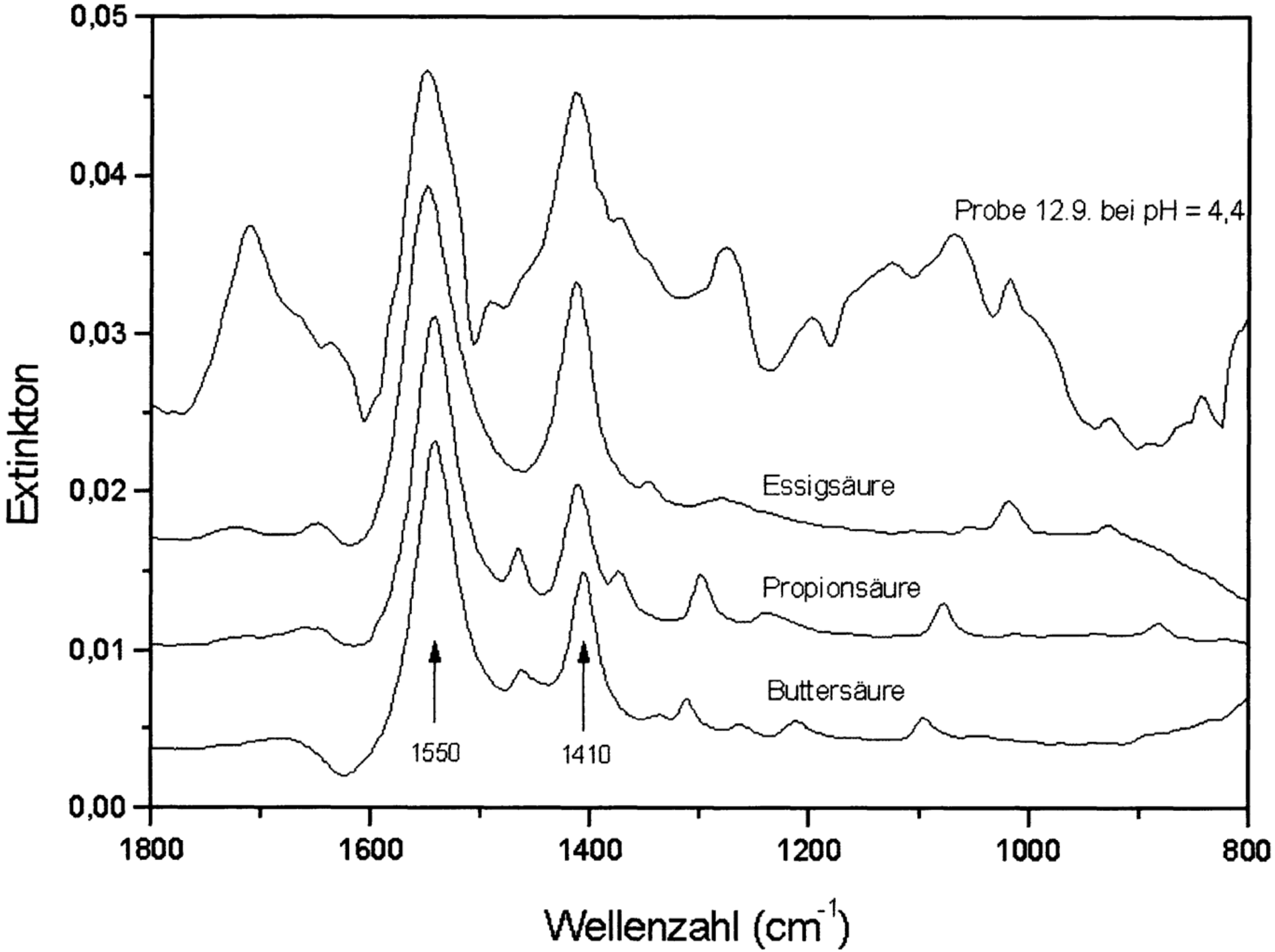
ATR-Measurement



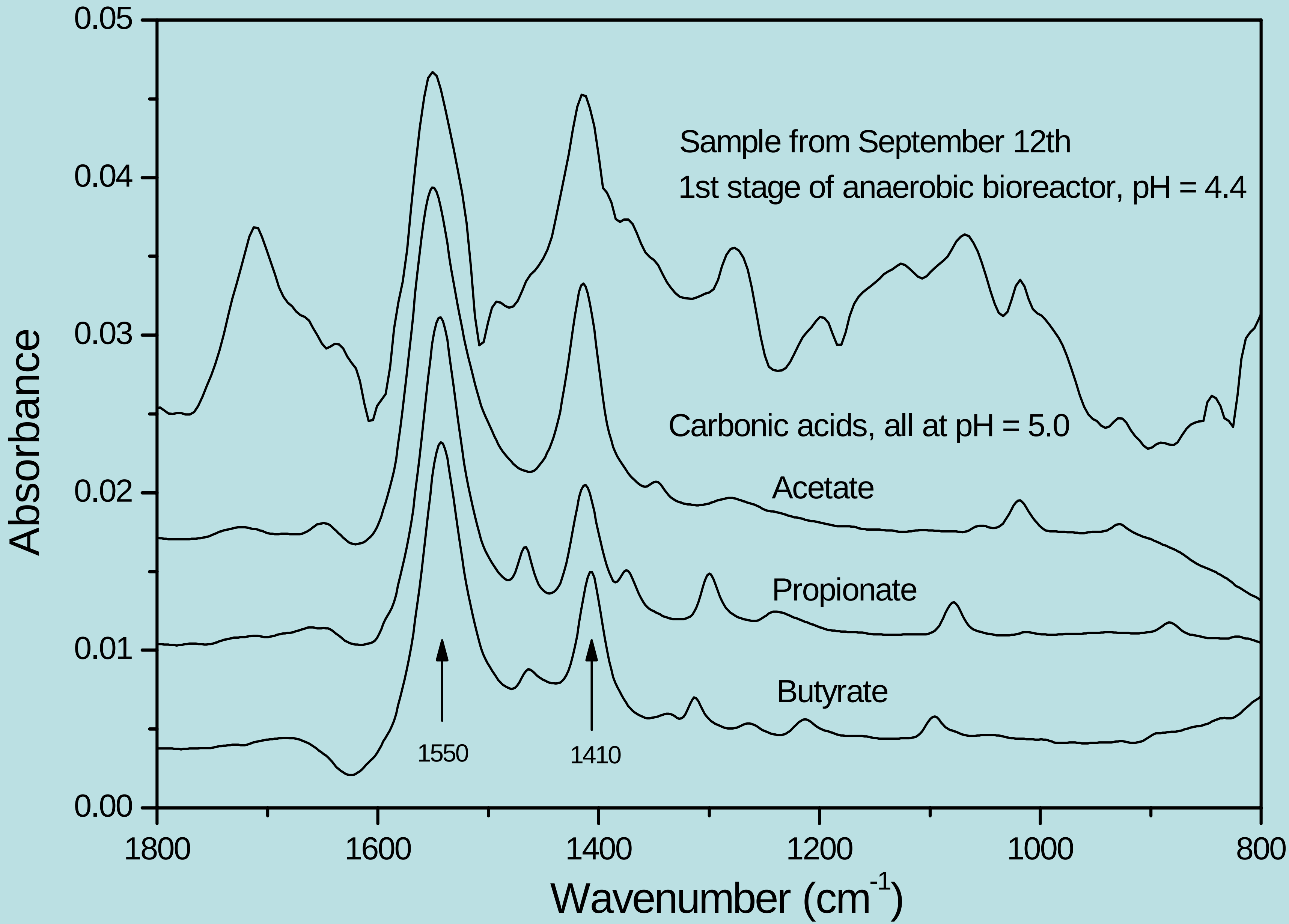
ATR-Measurement

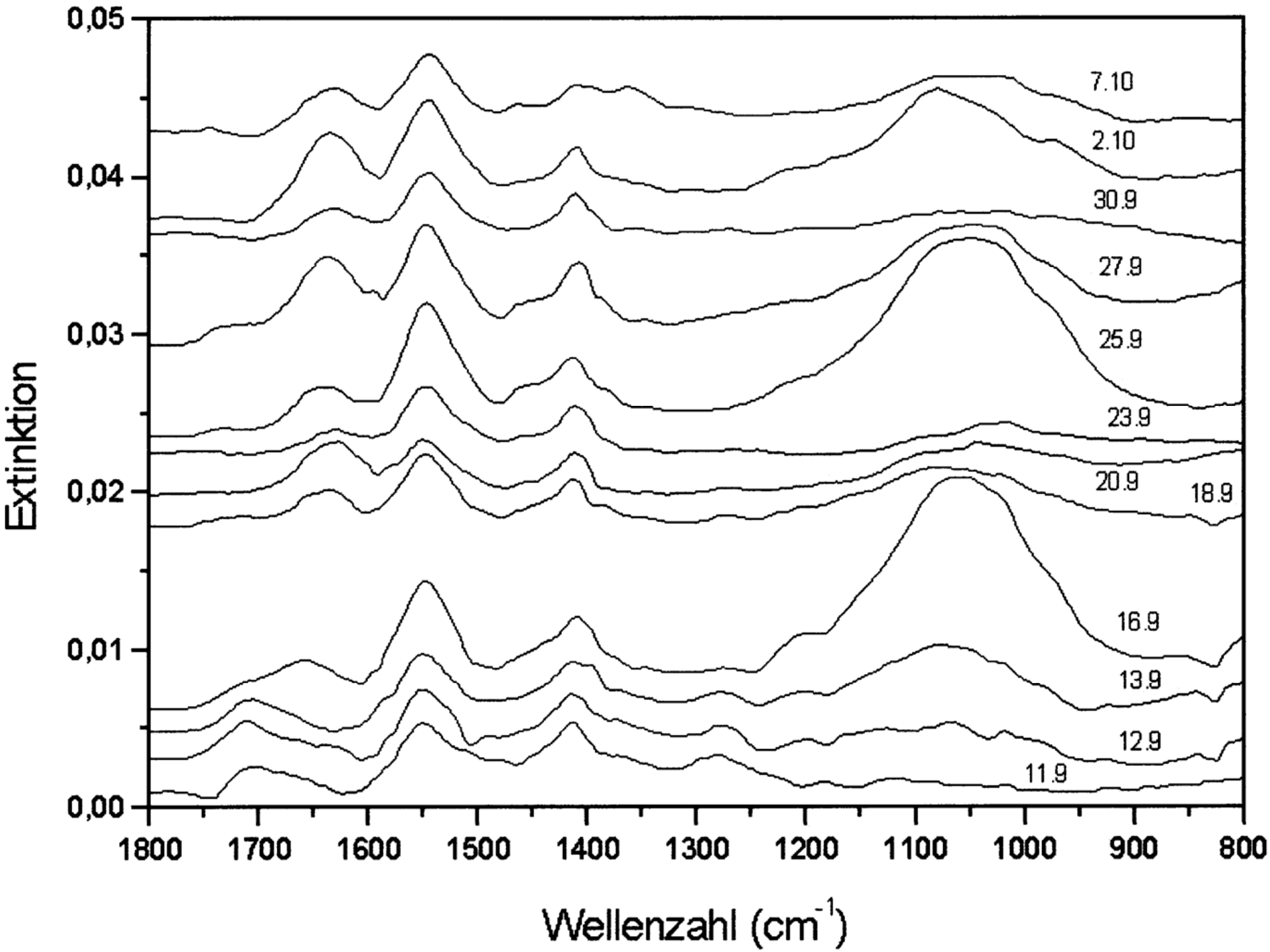


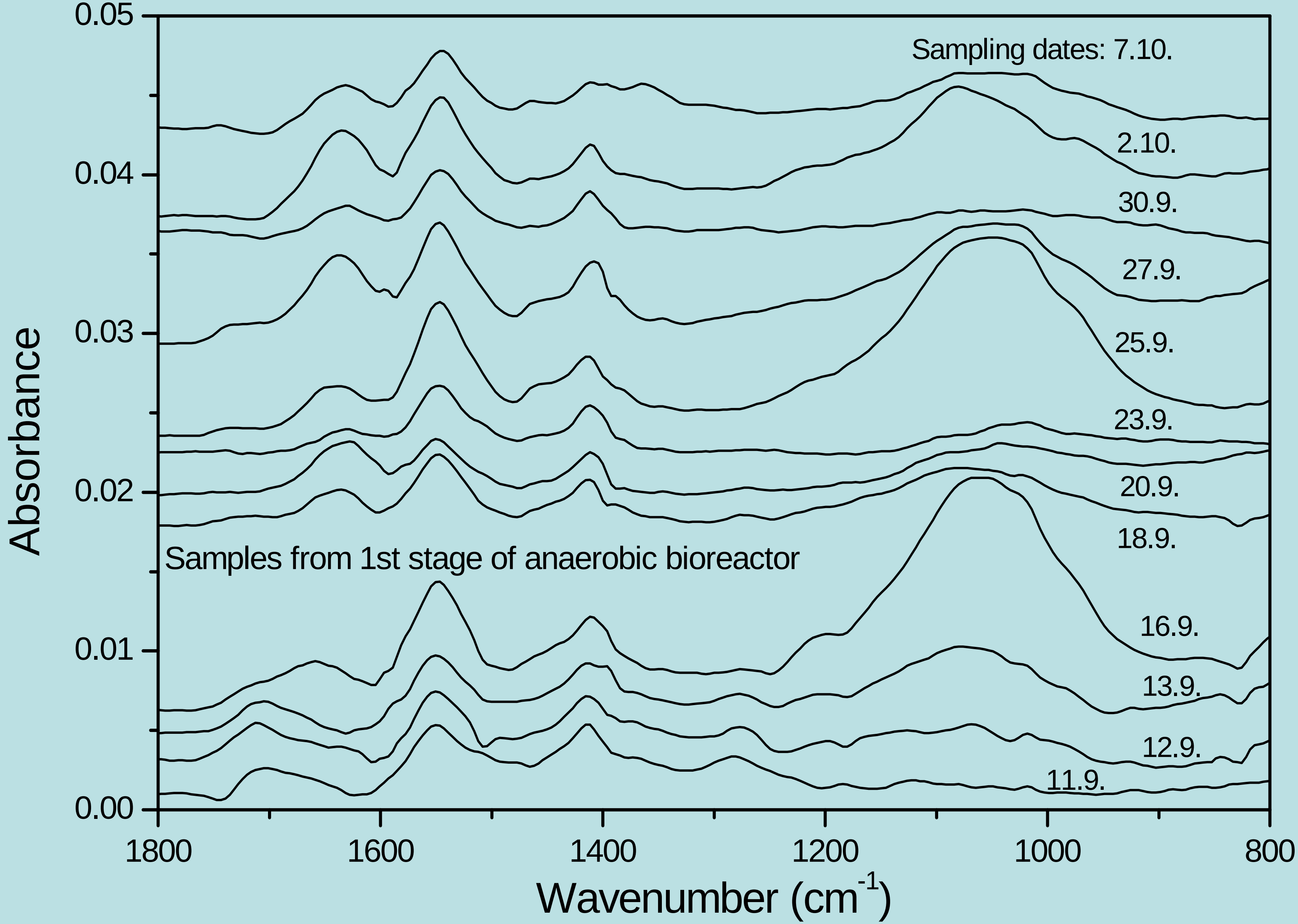




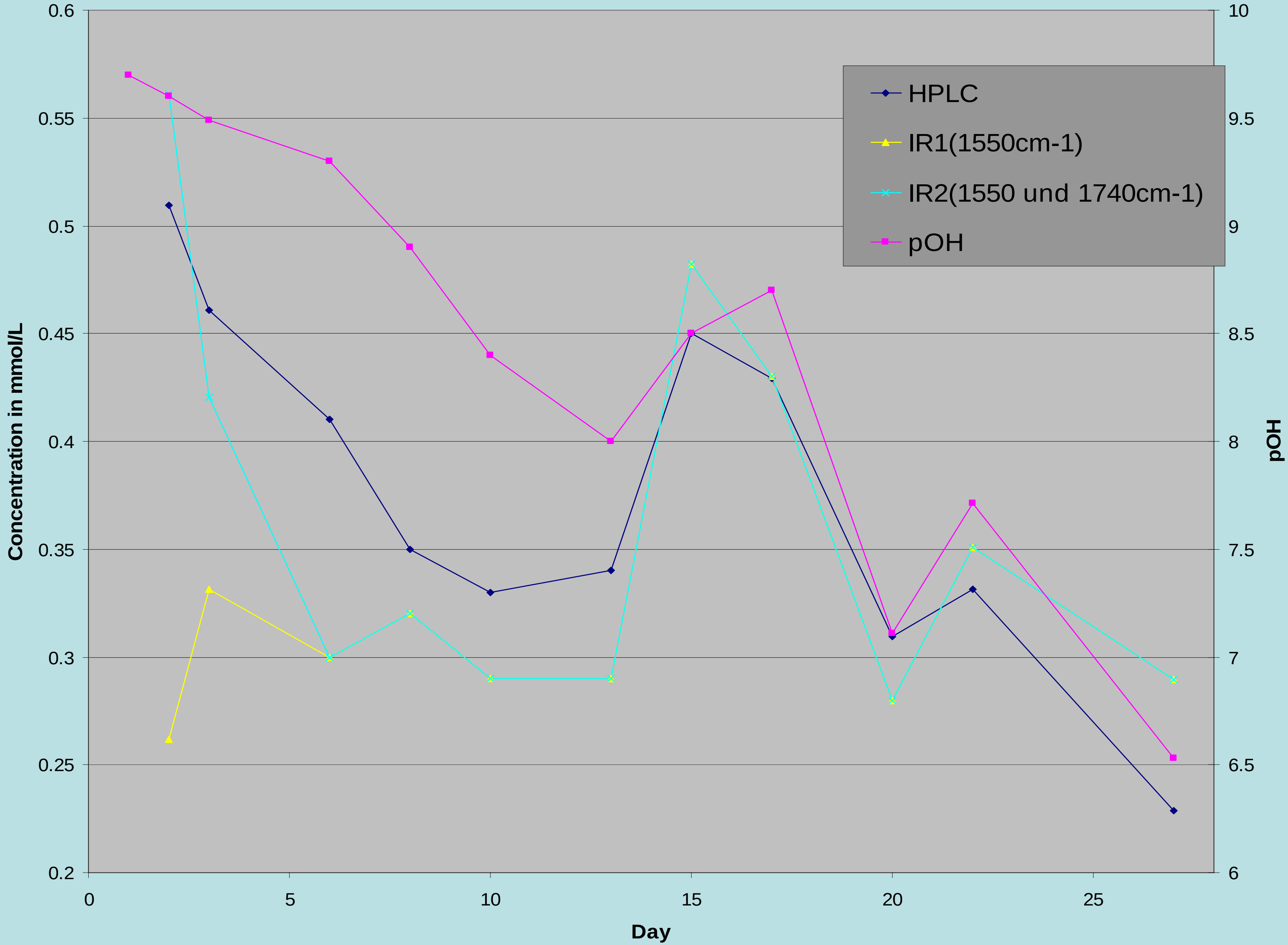
0,05
0,04
0,03
0,02
0,01
0,00
Extinkton
Probe 12.9. bei pH = 4,4
Essigsäure
Propionsäure
Buttersäure
1550
1410
1800
1600
1400
1200
1000
800
Wellenzahl (cm-1)

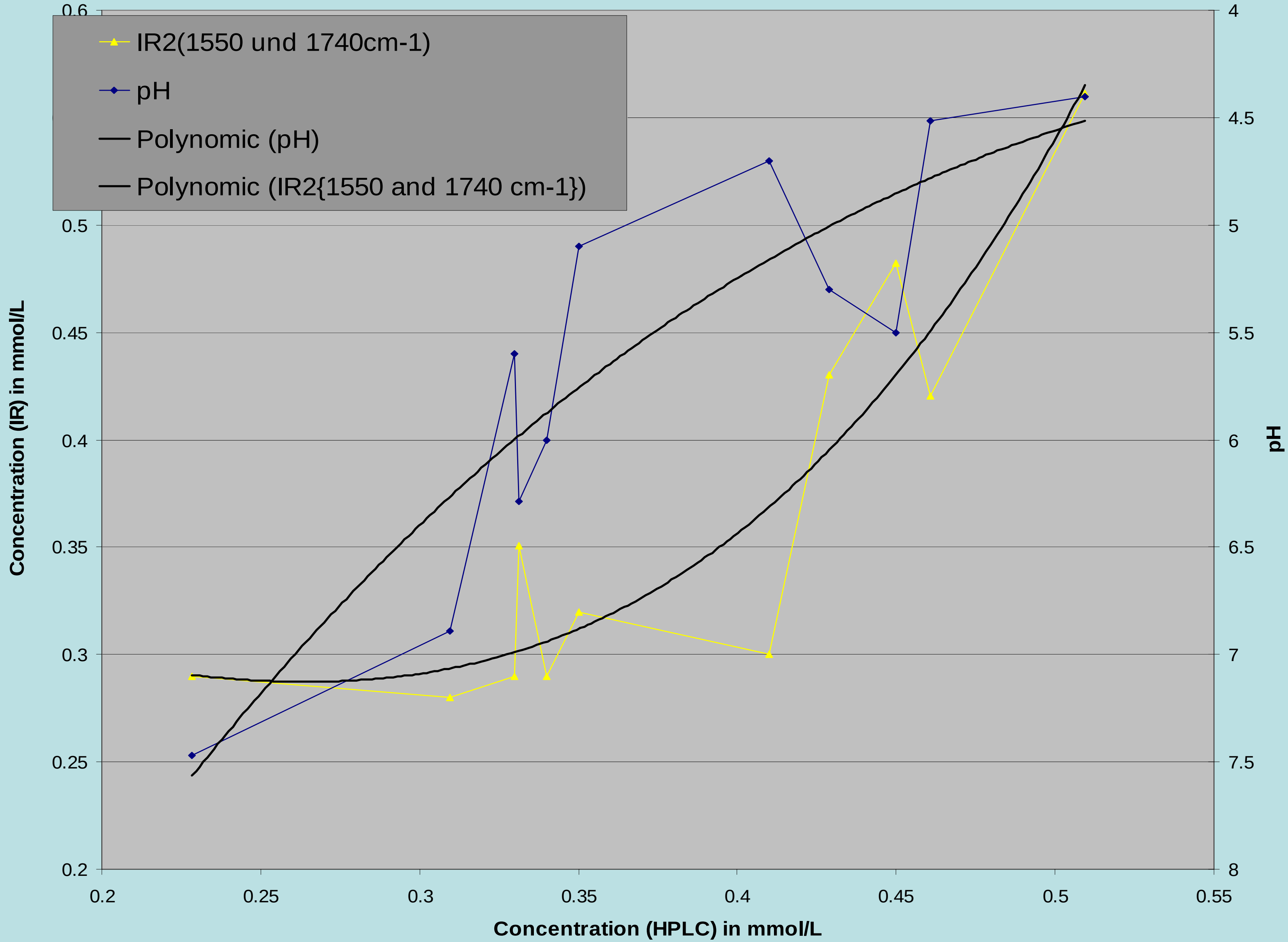

Sample from September 12th
1st stage of anaerobic bioreactor, pH = 4.4
Carbonic acids, all at pH = 5.0
Acetate
Propionate
Butyrate
1550
1410
Absorbance
0.05
0.04
0.03
0.02
0.01
0.00
1800
1600
1400
1200
1000
800
Wavenumber (cm-1)

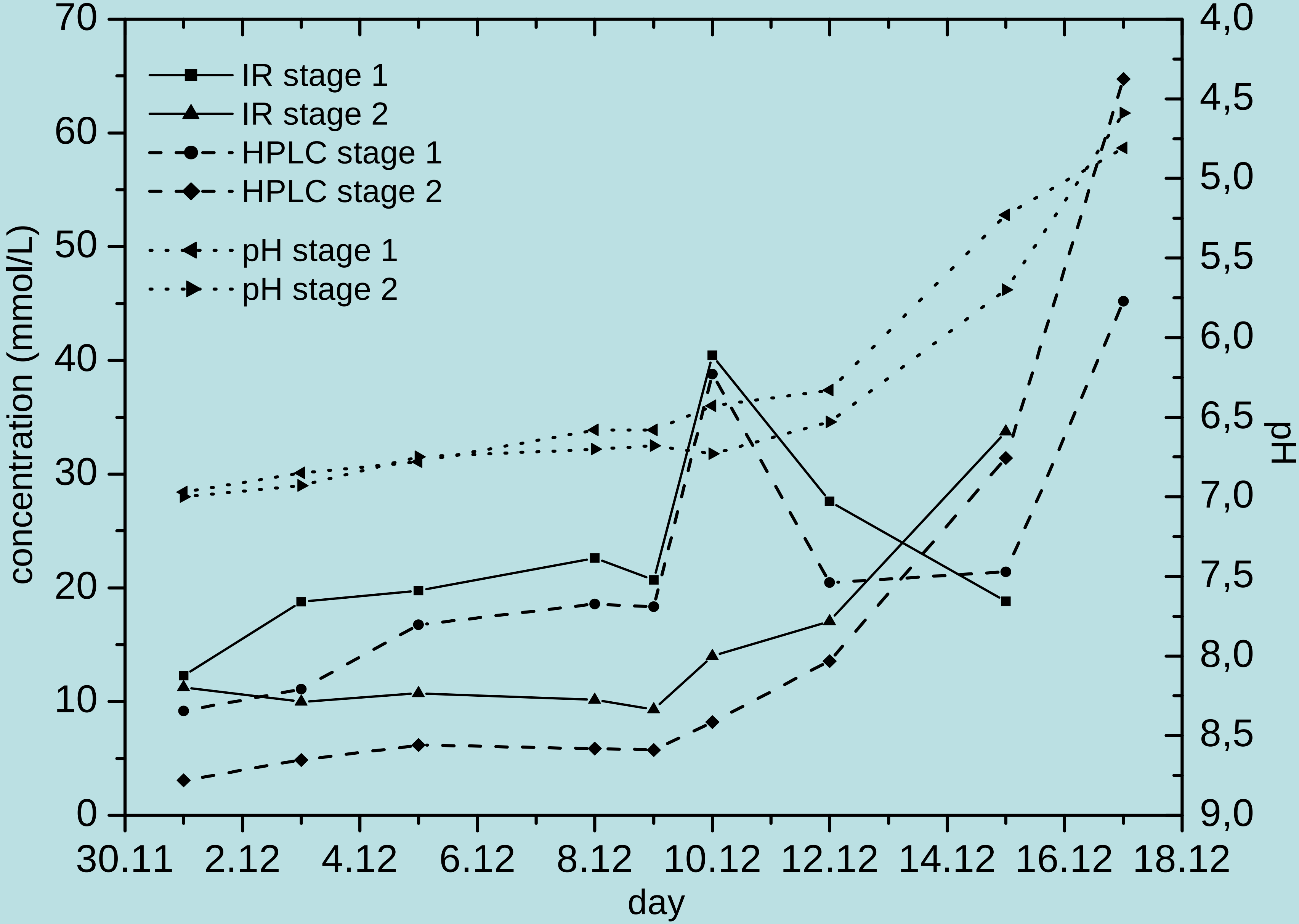

0,05
0,04
0,03
0,02
0,01
0,00
Extinktion
7.10
2.10
30.9
27.9
25.9
23.9
20.9
18.9
16.9
13.9
12.9
11.9
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
Wellenzahl (cm-1)



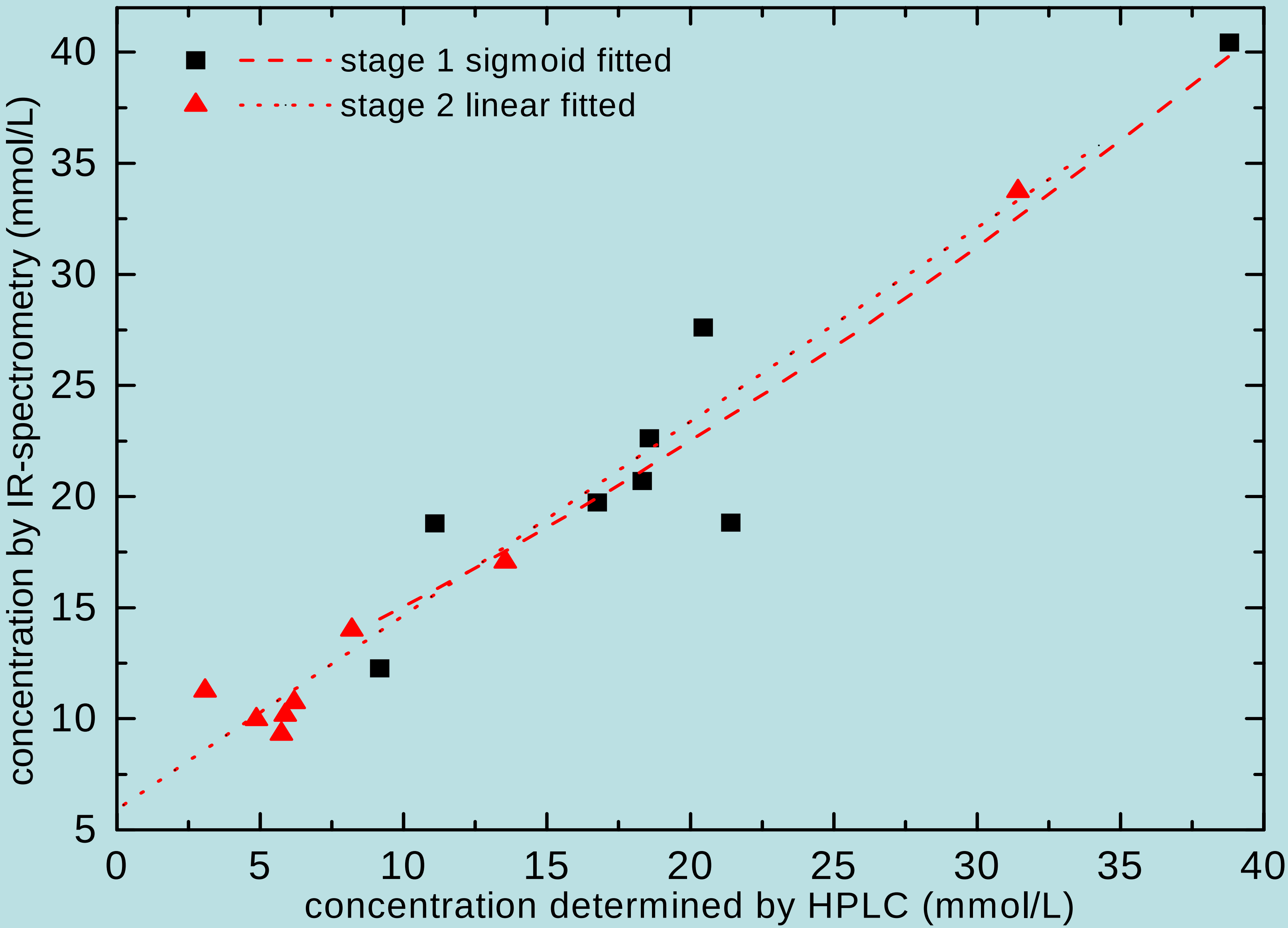
Sampling dates: 7.10.
2.10.
30.9.
27.9.
25.9.
23.9.
20.9.
18.9.
Samples from 1st stage of anaerobic bioreactor
16.9.
13.9.
12.9.
11.9.
Absorbance
0.05
0.04
0.03
0.02
0.01
0.00
1800
1600
1400
1200
1000
800
Wavenumber (cm-1)


HPLC
IR1(1550cm-1)
IR2(1550 und 1740cm-1)
pOH
Concentration in mmol/L
pOH
Day
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
10
9.5
9
8.5
8
7.5
7
6.5
6
0
5
10
15
20
25


IR2(1550 und 1740cm-1)
pH
Polynomic (pH)
Polynomic (IR2{1550 and 1740 cm-1})
Concentration (IR) in mmol/L
pH
Concentration (HPLC) in mmol/L
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0.6
4
4.5
5
5.5
6
6.5
7
7.5
8



IR stage 1
IR stage 2
HPLC stage 1
HPLC stage 2
pH stage 1
pH stage 2
concentration (mmol/L)
pH
day
0
10
20
30
40
50
60
70
4,0
4,5
5,0
5,5
6,0
6,5
7,0
7,5
8,0
8,5
9,0
30.11
2.12
4.12
6.12
8.12
10.12
12.12
14.12
16.12
18.12



stage 1 sigmoid fitted
stage 2 linear fitted
concentration by IR-spectrometry (mmol/L)
5
10
15
20
25
30
35
40
0
5
10
15
20
25
30
35
40
concentration determined by HPLC (mmol/L)

Reforming

Synthesegasgewinnung

(z. B. zur Ammoniak- und Methanolsynthese)

$$CH_4 + H_2O \xrightarrow[800\ ^{\circ}C]{Ni} CO + 3H_2$$

CO-Konvertierung

$$CO + H_2O \xrightarrow[500\ ^{\circ}C]{Fe/Cr\text{-}Oxid} CO_2 + H_2$$

Summenreaktion

$$CH_4 + 2H_2O \longrightarrow CO_2 + 4H_2$$

$35{,}9 MJ/m^3$ $\qquad$ $4 \cdot (10{,}8) MJ/m^3$

Summary and Conclusion

- An algal biomass based solar energy generator is possible
- There is a high efficient anaerobic process
- Higher organisms are problematic in the algal reacotor; nitric species in the anaerobic process
- Currently the process is not economic

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Acknowledgements

- German Ministry for Education and Research (BMBF) for funding this project (FKZ 170 02 01)
- ISAS - Institute for Analytical Sciences for the high engaged work on IR-Spectrometry