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Algae for wastewater treatment

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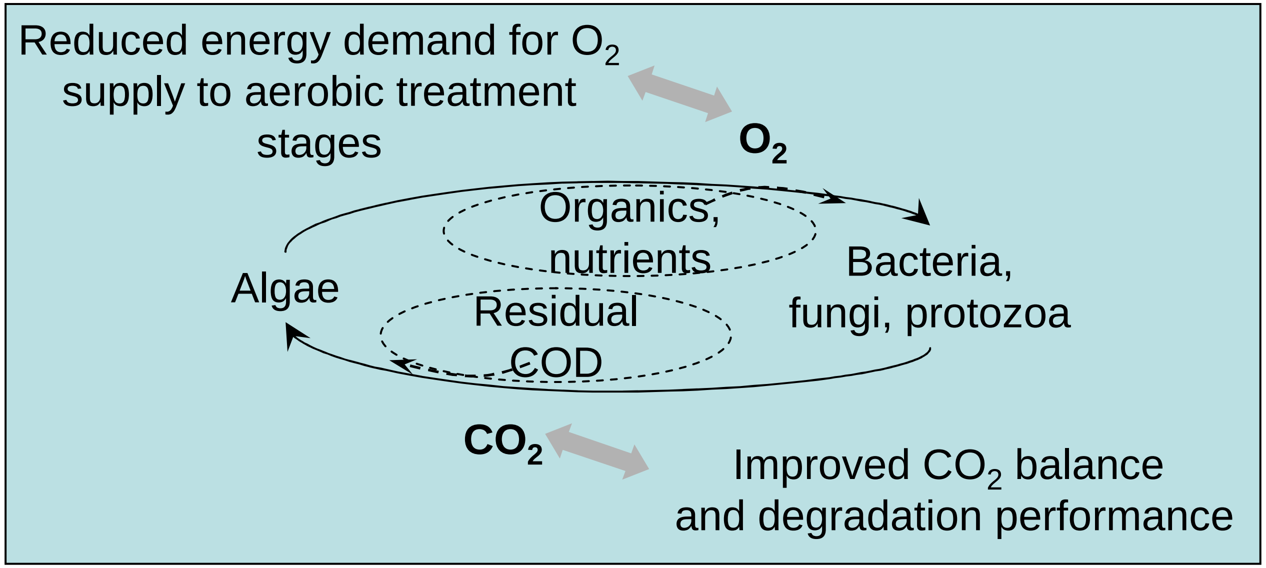
PTS Environment Symposium, 08th – 10th November 2011

contents

project basics and aim

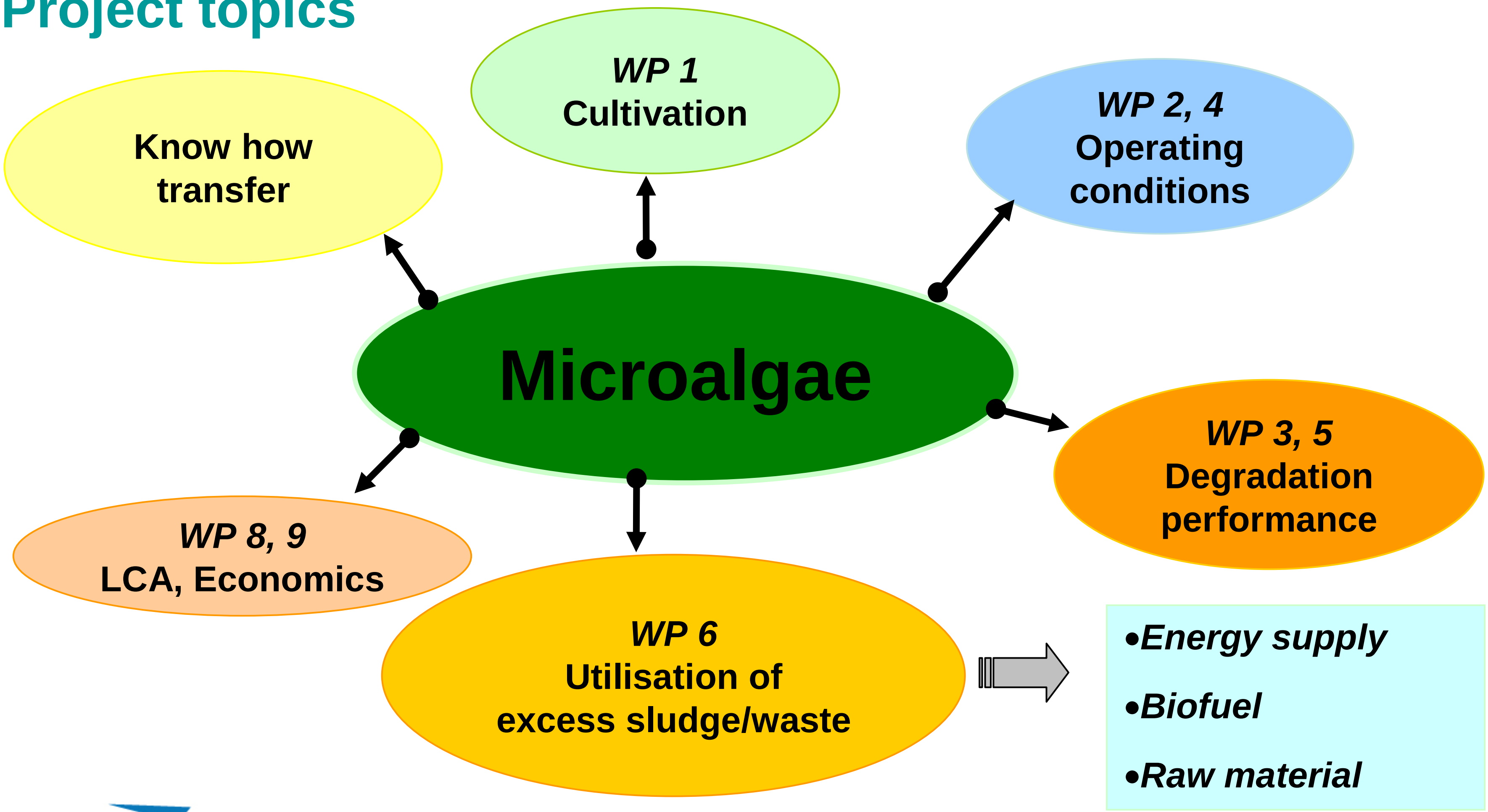
Title: Combined **al**gal and **ba**cterial waste water treatment for high environmental **qua**lity effluents (ALBAQUA)



issue applicable, efficient and economical for the paper industry?

project consortium

Project topics



Trials – overview lab scale tests

Cultivation

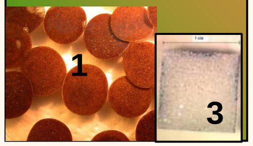
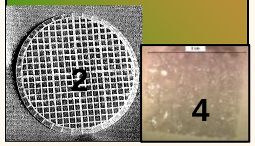
- Isolation of algae from paper mill effluents
- Cultivation and pre-selection of suitable algae species

Design parameters

- continuous operation of a lab scale waste water treatment unit
- operated with real waste water of a paper mill wwtp
- varying operating parameters
- Trials so far: with chlorella vulgaris

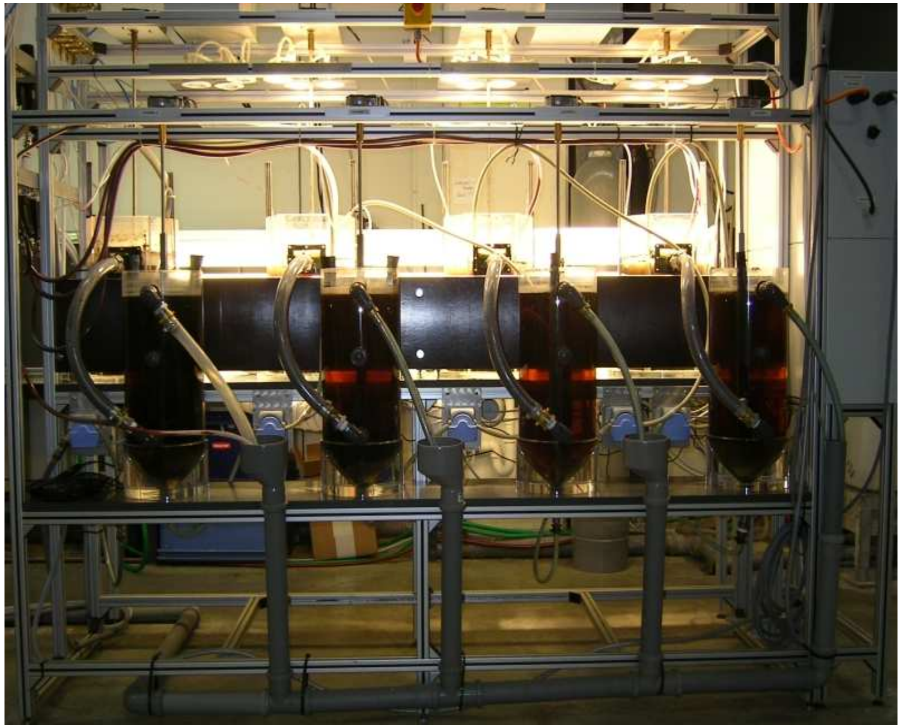
Trials – overview lab scale tests

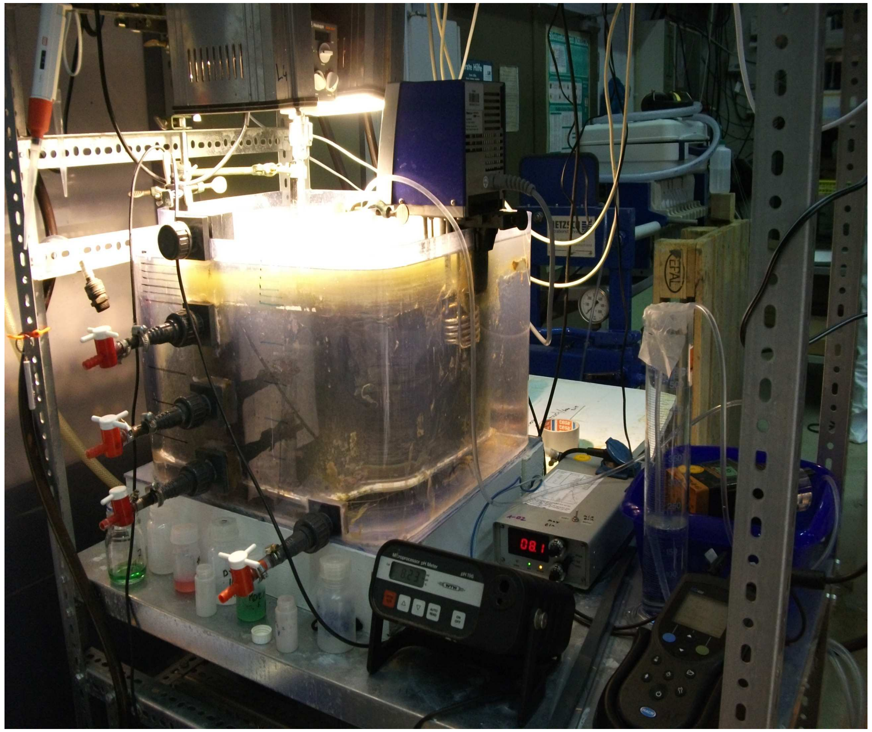
Degradation performance **parallel testing**

Algae fixation trials	**Conventional activated sludge**	**Algae-bacteria Biomass**	**Algae-bacteria Biomass +** 	**Algae-bacteria Biomass +** 	
Degradation performance of various effluents from paper industry	**Algae-bacteria Biomass + Effluent 1**	**Algae-bacteria Biomass + Effluent 2**	**Algae-bacteria Biomass + effluent 3**	**Algae-bacteria Biomass + Effluent 4**	**Single Algae-Biomass**

Nearly similar operating conditions in all bioreactors
Currently all trials with *chlorella vulgaris*

Trials – lab scale plants





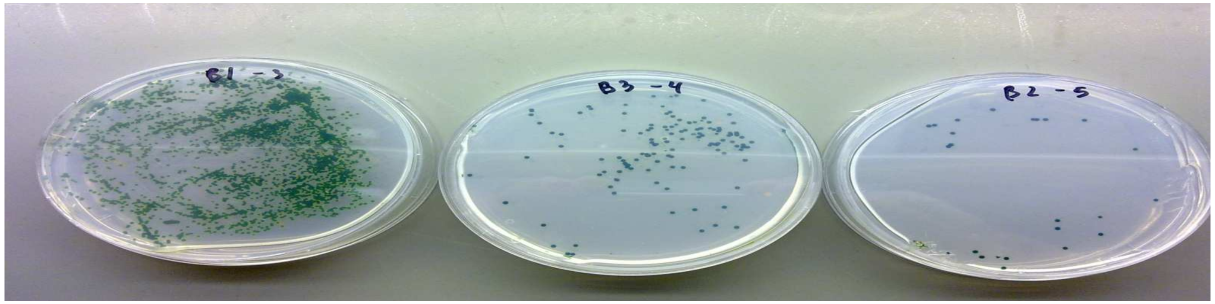
Trials – operating conditions and parameters

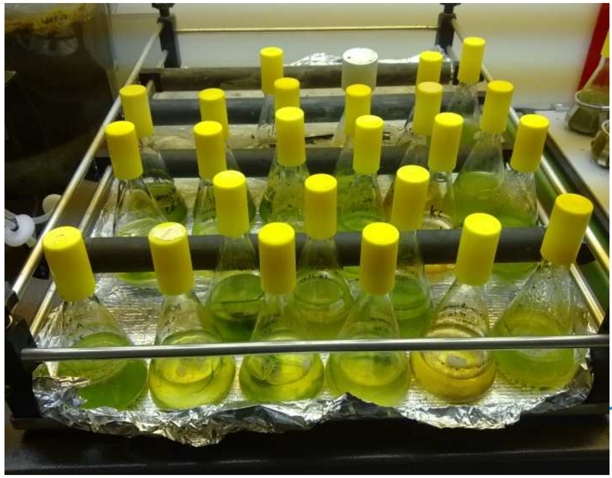
Operating parameter	Lab scale trials	Pilot trials
F/M	0,05–0,1 kg BOD_5/(kg dsm.d)	0,03 – 0,09 BOD : VS
HRT	2–5 d	2 d, 3,8 d, 1,8 d
DSM	0,3–2,5 g/l	0,5 – 2,5 g/l
nutrition load	C:N:P = 1100:6:0,5	
O_2 concentration	2–6 mg/l (supplied by algae – no aeration)	2–8 mg/l (supplied by algae – no aeration)
temperature/pH	T 25 – 30°C; pH 7,5-8,5	T 15 – 30°C; pH 7,5-9,5
lighting	10:14 h and 12:12 h	natural daylight
measured parameter	Chl-a, DSM, COD, BOD_5, TOC, NH_4, NO_3, NO_2, PO_4 (partly: microorganism composition) **TOC (DOC)**	
calculated parameter	HRT, F/M, SRT, algae:bacteria ratio	

Results – algae isolation and cultivation

Example: algae observed in paper mill effluent

Isolation: dilution method by plating on agar plates

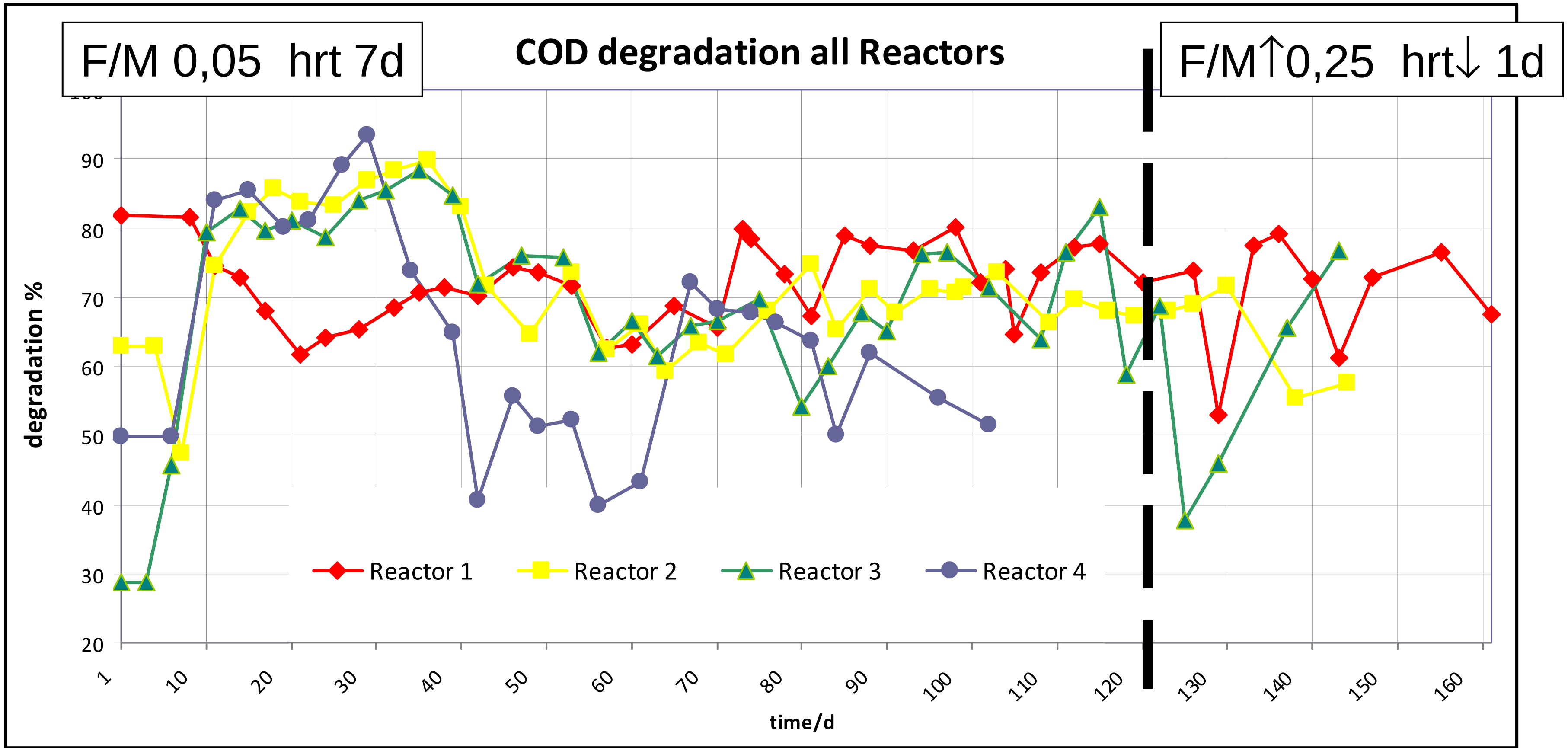




Re-suspension in medium of the isolated cells after plating

→ **6 algae species suitable for paper industry effluent treatment found**

Results – examples effluent degradation



Results - sedimentation of algae-bacteria-biomass

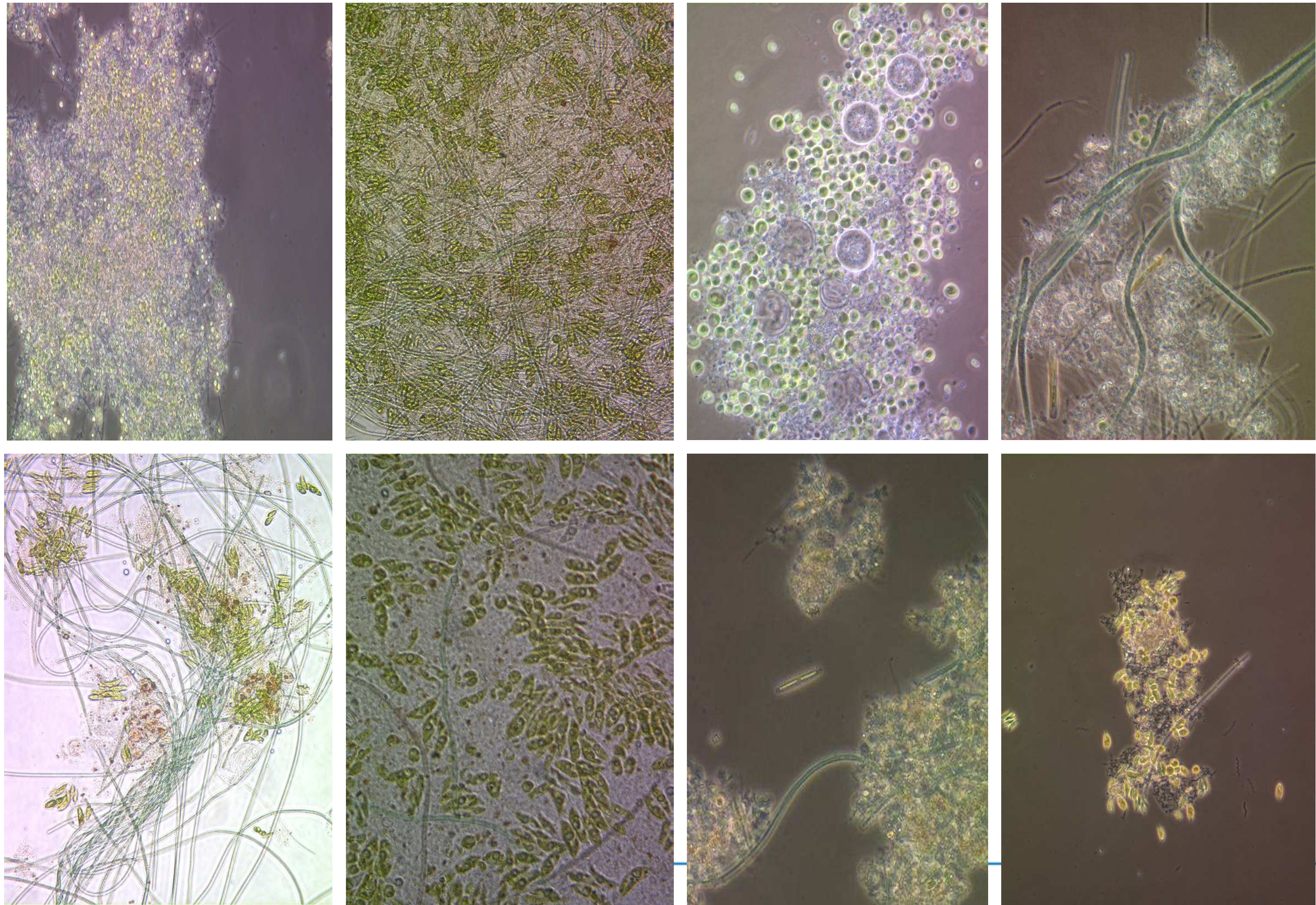
before

after 2h

SVI: 30-40 ml/g

Good settling conditions

Results - microscopic investigation



Results – summary effluents degradation

paper mill	Raw material	Products	Settle-ability	∅Degradation performance	No ext. Aeration	Chl a+b µg/ml	O_2
1	Mech. pulp, waste paper	printing papers	☺	80 %	👎	👎	👎
			☺	70 %	☺	≤ 12	☺
2	pulp, waste paper	wood containing coated printing paper	☺	65 %	👎	👎	👎
3			☺	80%	👎	👎	👎
4	waste paper	board	☺	70 %	☺	≤ 16	☺
5	pulp	Woodfree graphic paper	☺	76 %	☺	≤ 14	☺
6	waste paper	board	☺	72 %	☺	≤ 23	☺
7	waste paper	board	☺	70 %	☺	≤ 12	☺
8	waste paper, pulp	Woodfree graphic paper	☺	76 %	☺	≤ 12	☺
9	waste paper, mech. pulp	Newsprint	☺	65 %	☺	≤ 16	😐

Results – algae-bacteria biomass characteristics

Parameter	Mixed sludges	Activated sludge	Algae
Ash (%)	35 - 68	44	9
C (%)	23 - 34	36	46
N (%)	2,6 – 5,7	4,4	7,8
P (%)	2,0 – 3,9	2,2	4,4
Algae (%)	2,0 – 12	/	/
Heating value (MJ/kg)	8 - 12	7	25,8* (Scenedesmus) 29* (Chlorella)

Trials –pilot plant

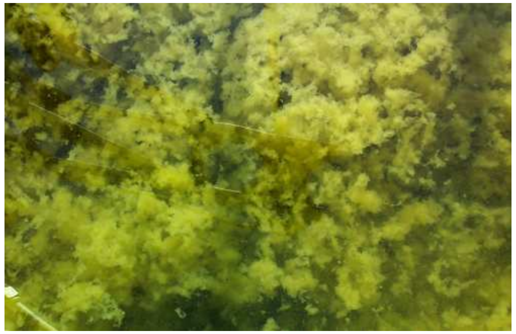
Characteristics Slovenian paper mill

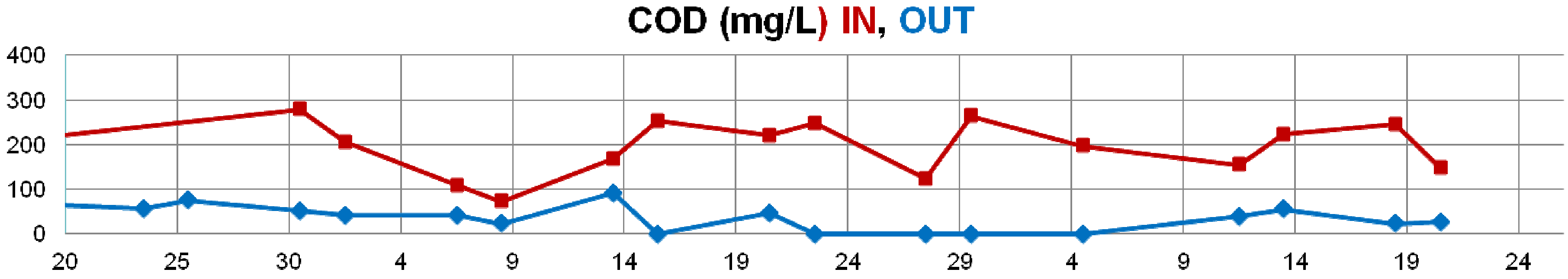
Production printing paper (primary fibers, different programs)

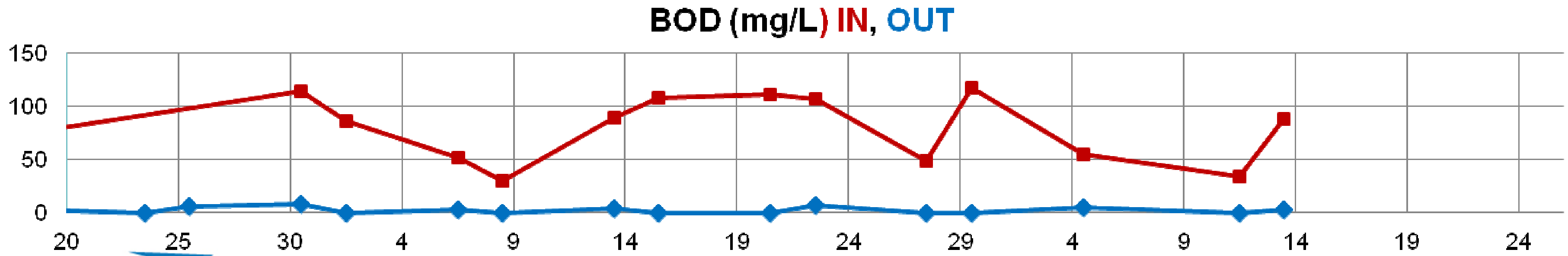
wwtp chemo-mechanical waste water treatment
volume of treated water: 3,000 m^3/day, 1,065,000 m^3/year
volume of sludge produced: 1,800 t/year

Effluent quality			Limit output values
Suspended solids		15 mg/l	80 mg/l
COD		50 – 400 mg/l ** →	110 mg/l
BOD		20 – 80 mg/l ** →	20 mg/l
N, P	total	< 3 mg/l	N (15 mg/l); P (3 mg/l)
pH		7	
Temperature		30 – 39 °C	

Results – pilot operation







Lessons learned

•Algal bacterial community develops into a **natural** mix

•Sufficient oxigenation is easily achieved with large margin

•Major threat: Chironomidae larvae consume the sludge (algae first)
➔ physical barriers (cover, insect net), occasional violent mixing and/or biological agents (Bti, Bs) integrated into the bacterial sludge

•Some additional (clean) algae inoculation will be necessary

•Insolation is **not** a major constraint, temperature and mixing are more important

•Flocculation is easy; thinking of more violent mixing to prevent insects, flocculation and sedimentation in the reactor and have more time for the flocculation in the sedimenter

•On-line control of nutrients and Chl a will be required

•Sludge is being tested for biogas (with good preliminary results)

Recommendations for operation

- HRT between 1-3 day(s) depending of the wastewater COD
- For highly polluted wastewaters (COD over 800 mg/l) this system can not be suggested.
- A biomass conc. 1.5 – 2.5 g/l and a SRT of 16-20 days favour the algae growth.
- A sedimentation time of 2 – 3 hours can be selected.
- Since there are no blowers in the system, stirrers are needed to keep the flocs suspended → dead zones have to be avoided.
- O_2 and pH of the system should be monitored.
- The colour of the system is a good indicator of system health.
- Intermittent aeration with blowers will favour the heterotrophic bacteria in the system and therefore it has to be avoided.

Summary

- good settling of algal-bacterial biomass most of the time and for most treated effluents from paper industry
- good degradation results
- no external aeration necessary in algae-bacteria-bioreactors; sufficient O_2 concentration for bacterial heterotrophic degradation activity supplied by algae photosynthesis activity
- extrusion/devour of algae by excess bacterial biomass growth under operating conditions of

  HRT<24 h, DSM_{total}> 3 g/l, B_{TS} > 0,25 kg BSB_5/(kg TS d)
- unsatisfactory settling of algae on carriers/extrusion of algae by bacterial biomass
- Necessity of operation of covered/closed bioreactor system under natural conditions due to serious contamination problems (larvae)

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cornet

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Thank you for your kind attention!

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http://www.cornet-albaqua.eu/

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