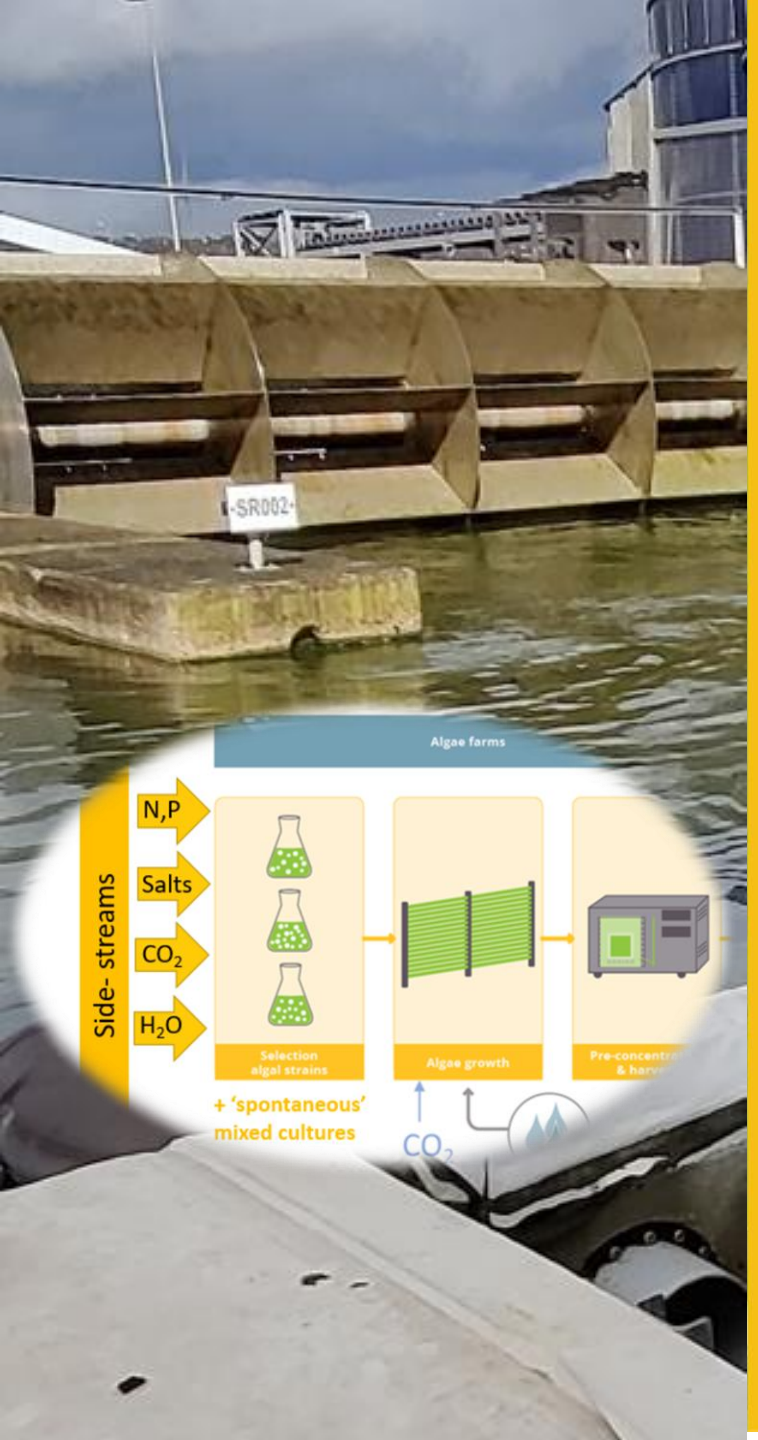


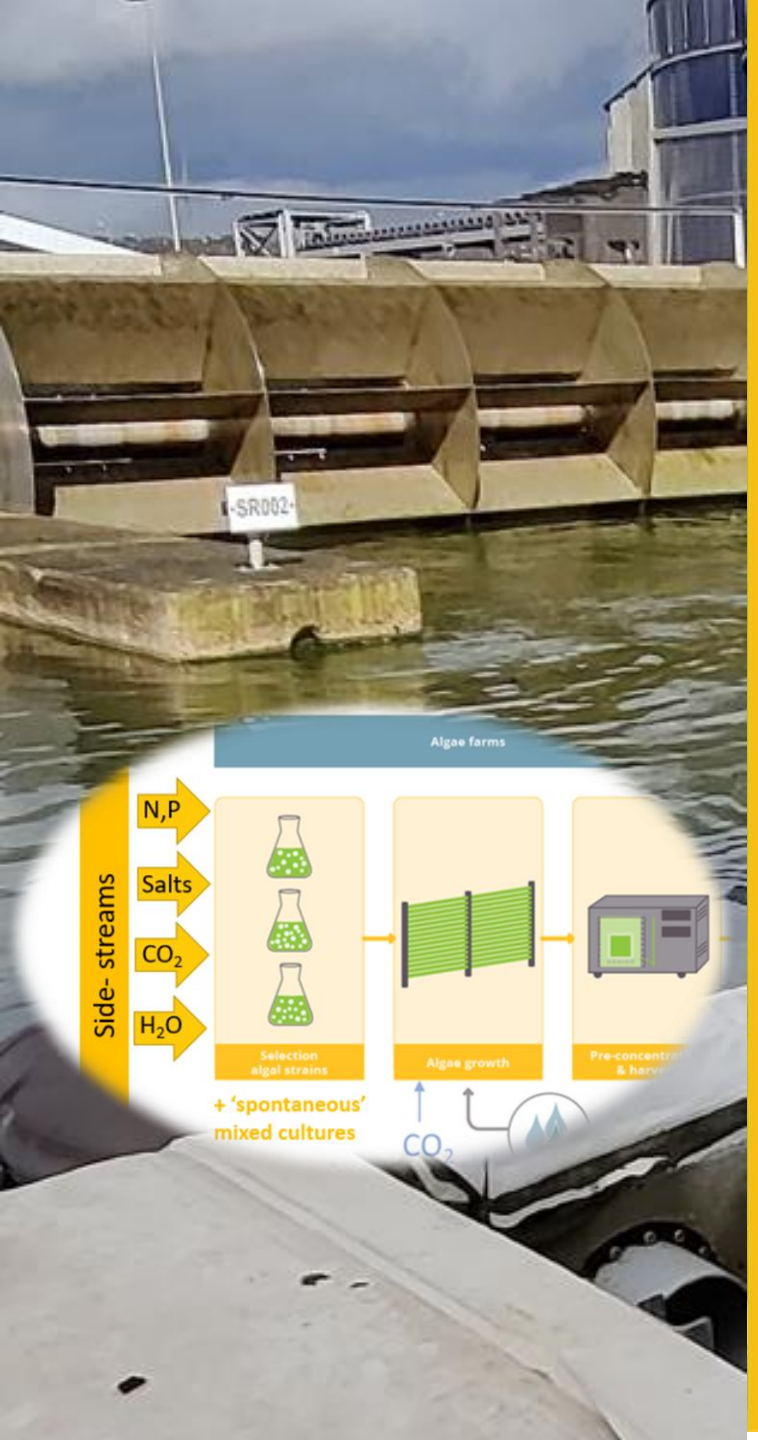
Algae biomass production on low organic carbon containing process water from a demineralization plant.

Final IDEA+ event, September 2023

Dimitri Overmeire – Yara (The Netherlands)

Leen Bastiaens – VITO (Belgium)

Floris Schoeters – Thomas More Radius (Belgium)



Removal of nitrogen from process water originating from a demineralization plant by algae grown in open ponds

Final IDEA+ event, September 2023

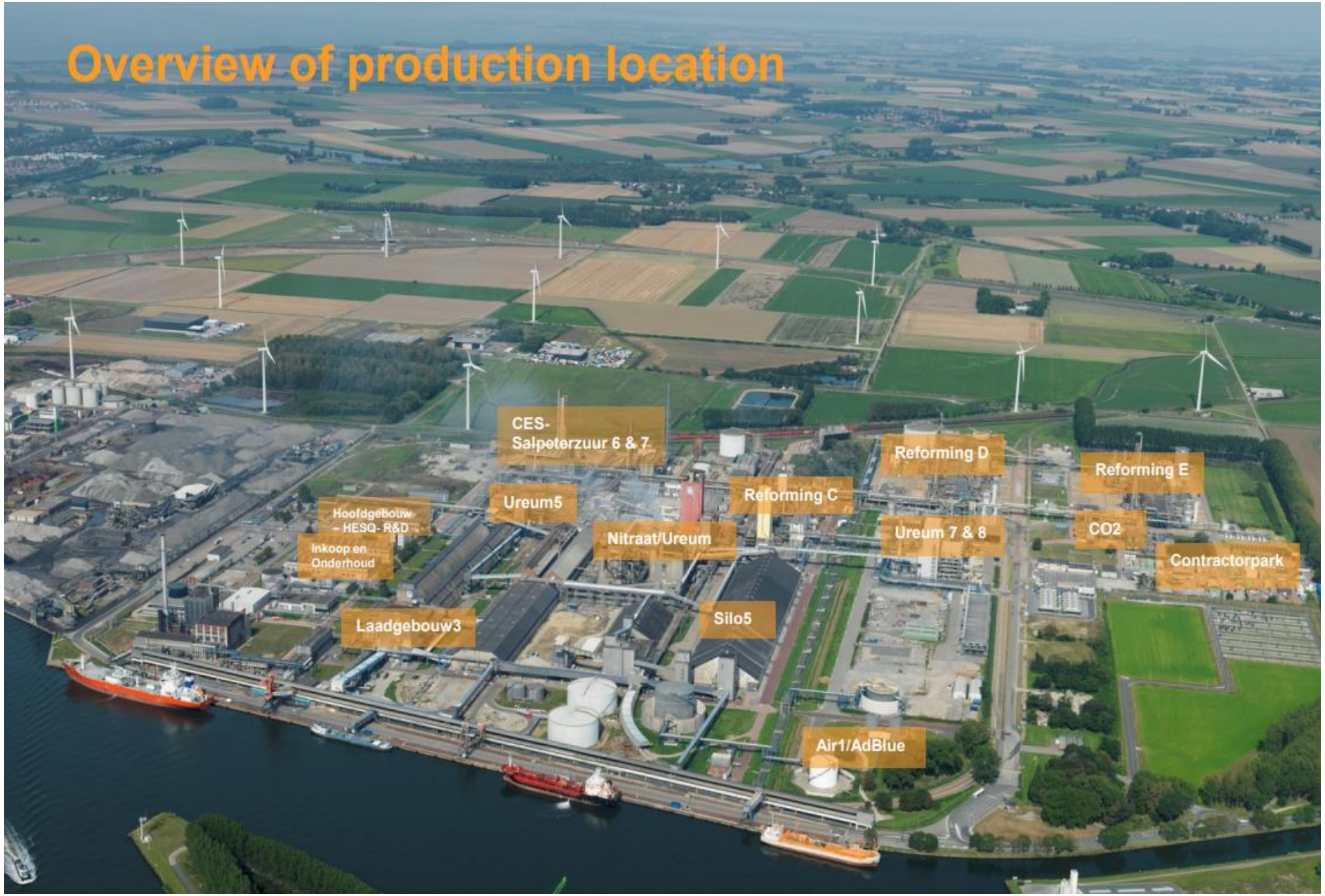
Dimitri Overmeire, Paul Van Elslande - Yara

Knowledge grows

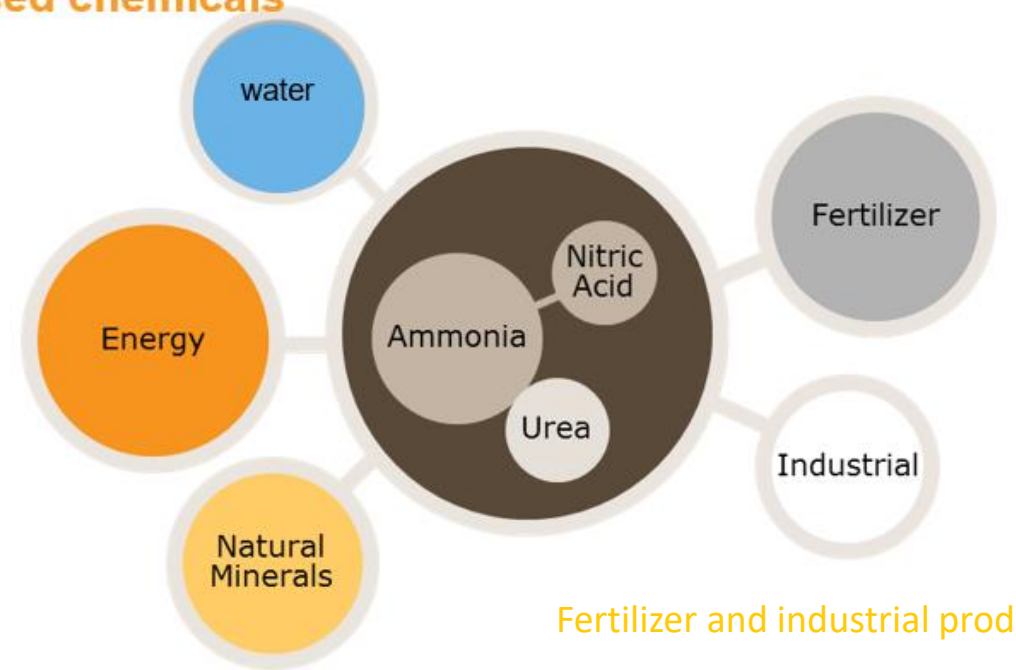
Algae presentation VITO

28/9/2023

Overview of production location



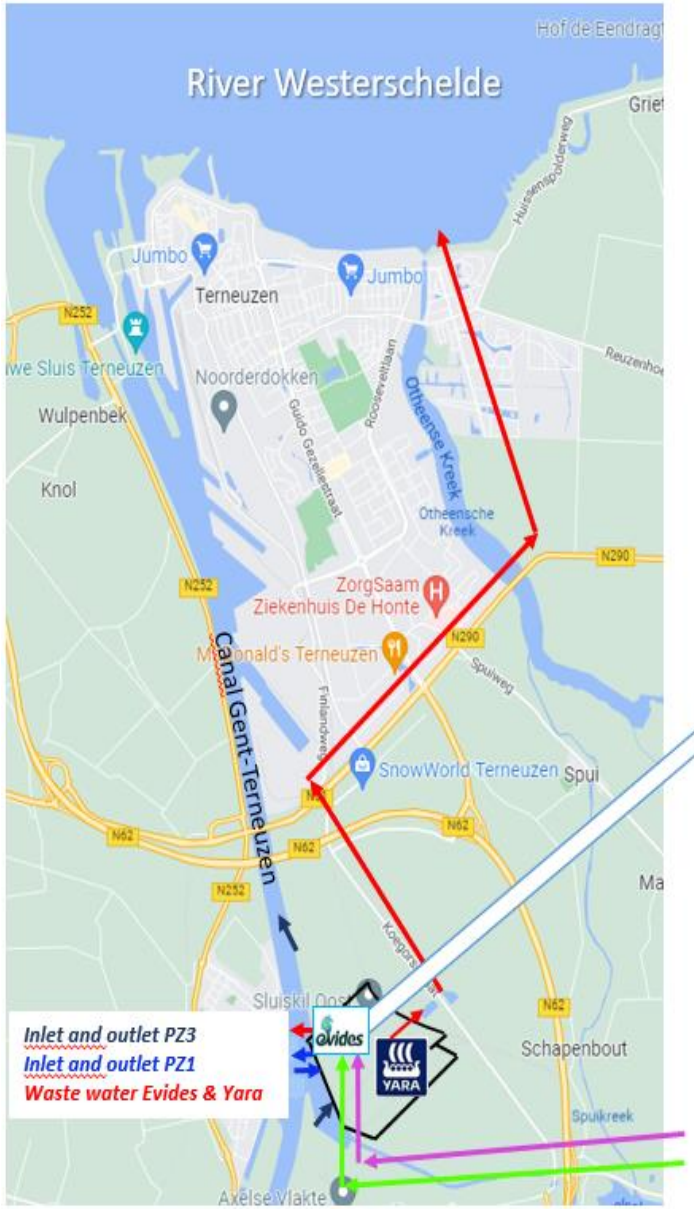
Ammonia, the backbone for fertilizers and nitrogen based chemicals

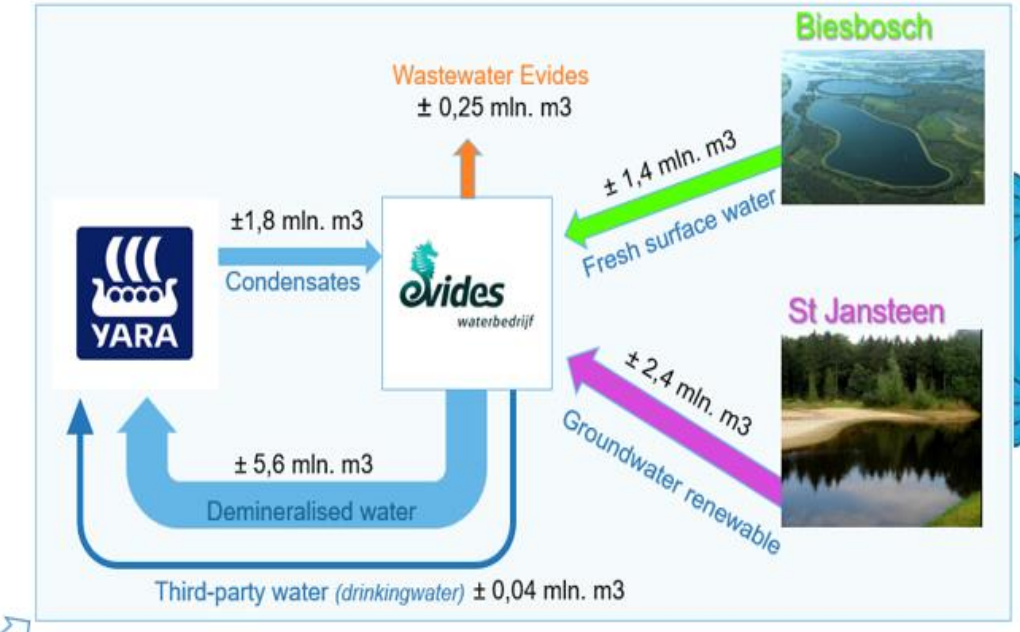


Fertilizer and industrial products with which we :

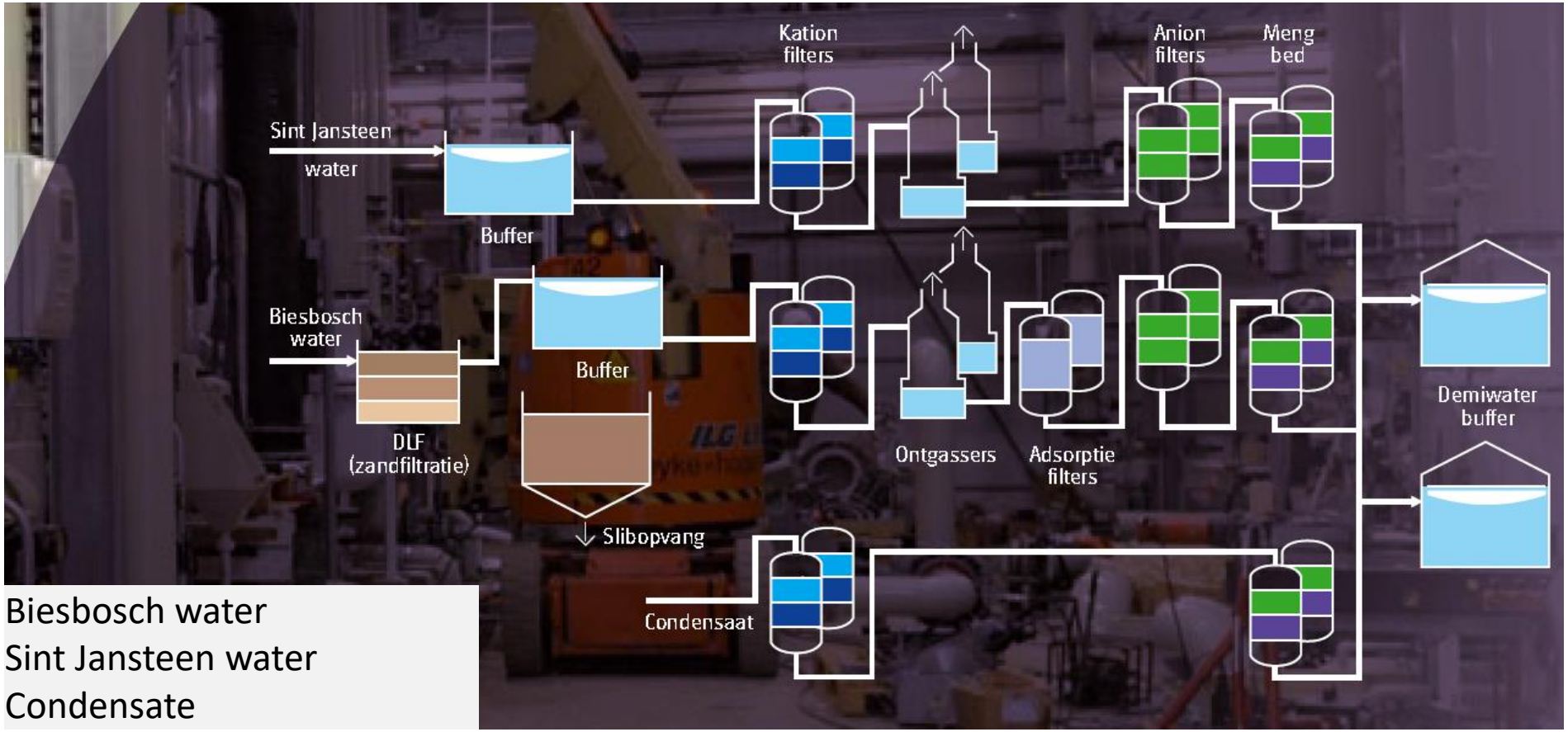
- ✓ make 50% of our food
- ✓ help the farmers aim for a healthy, defensive and highly productive crop
- ✓ reduce the Nox emissions of industry, ships, trucks and cars
- ✓ deliver nutrients and heat to the greenhouses
- ✓ can transport energy (Hydrogen)
- ✓ …

Wateruse Yara Sluiskil overview





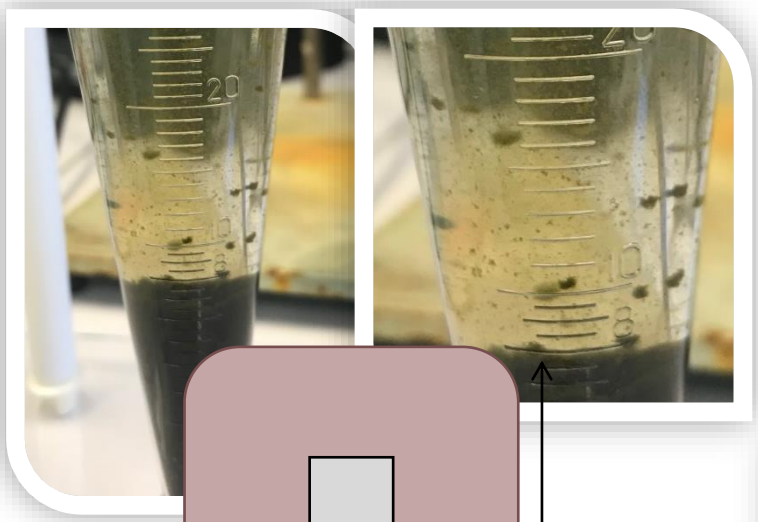
Demineralisation plant Evides



Biesbosch water
Sint Jansteen water
Condensate


YARA
Knowledge grows

Open raceway pond



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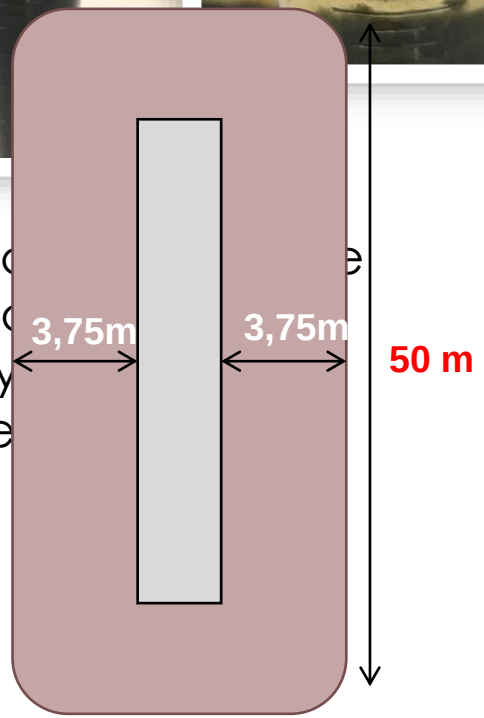
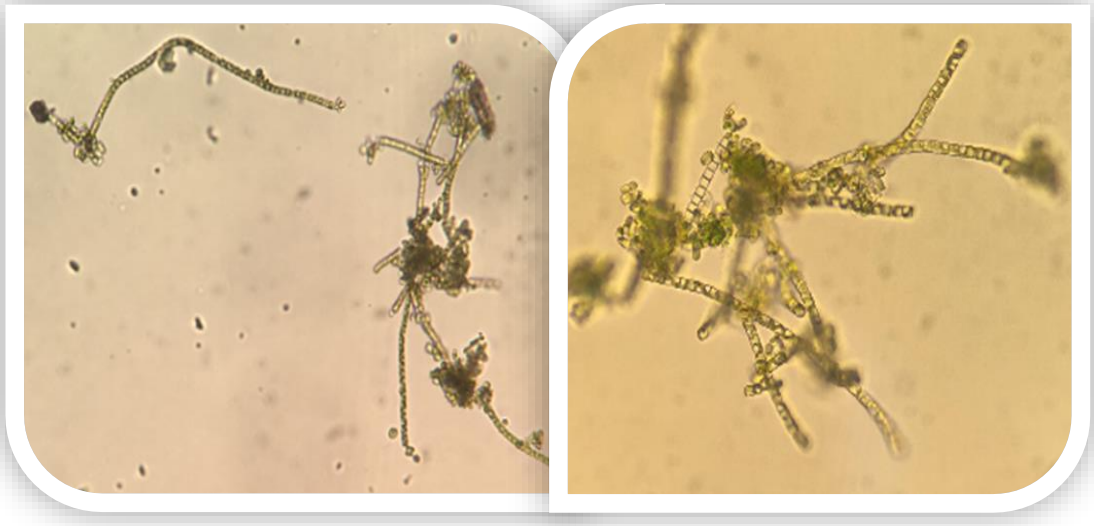
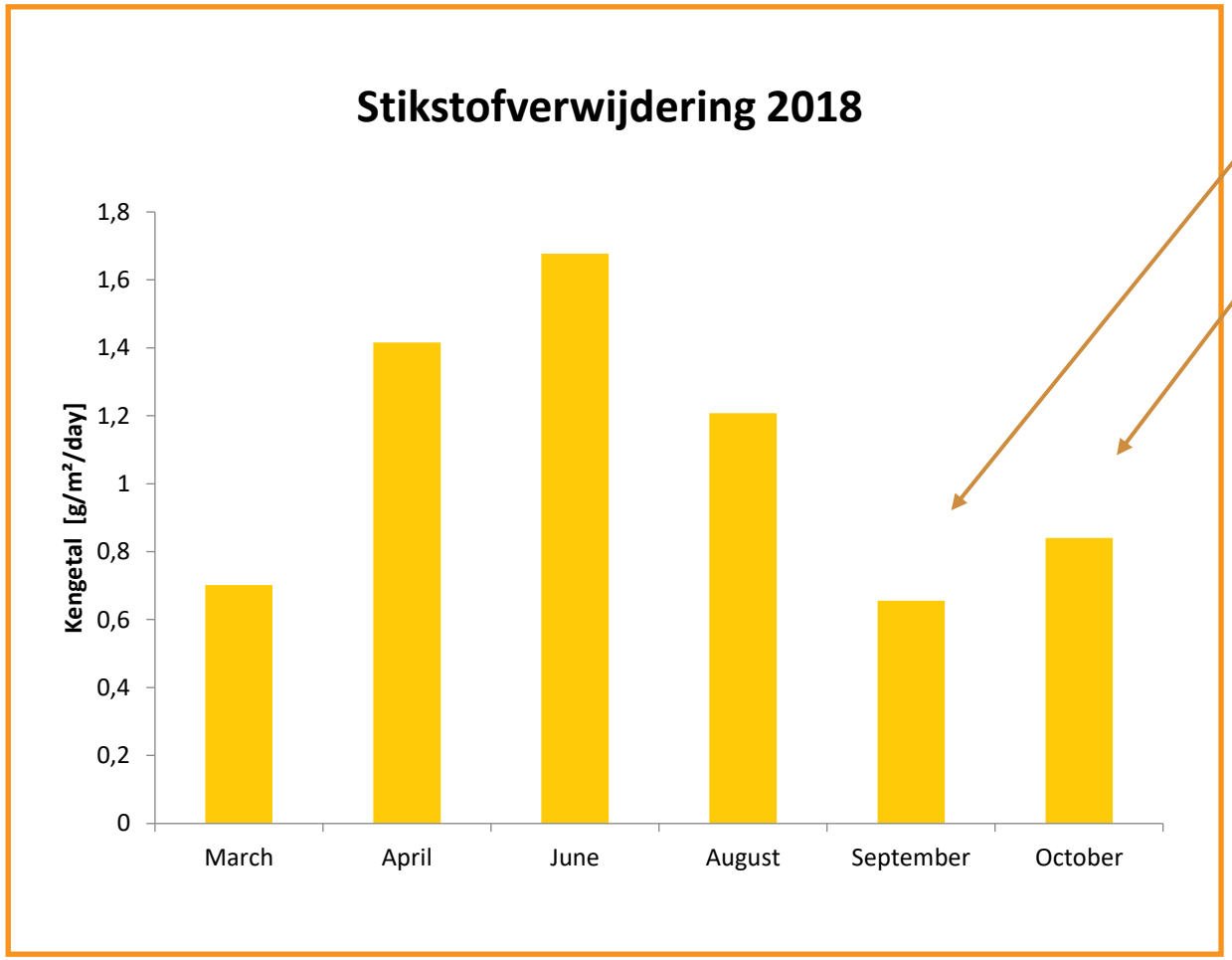




Nitrogen removal during a half year intens testing



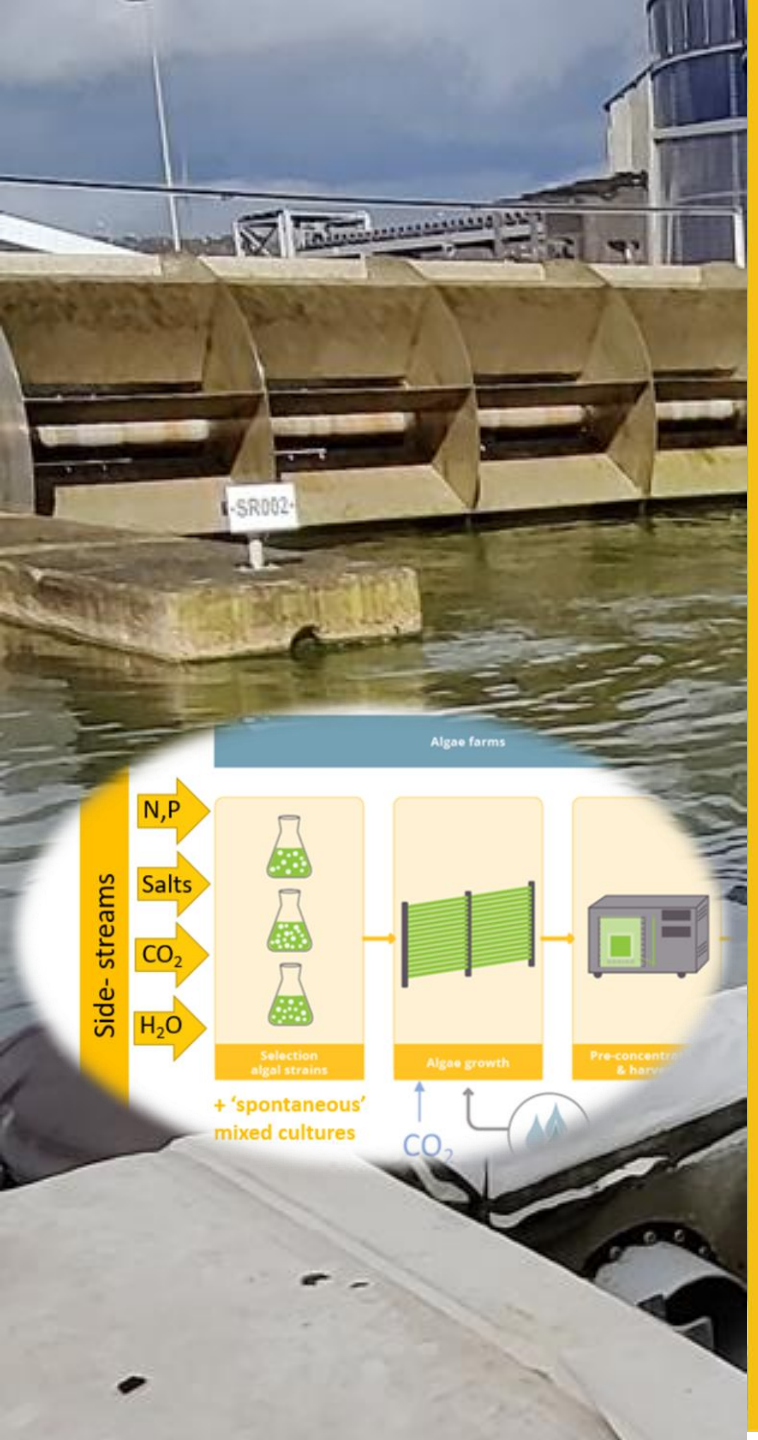
Bad weather in sept

A lot of sunshine in oct

Yearly average:
0.8 gN/m²/day

Full scale indication:
3.8 ha

N removal:
10.7 tonN/year



Harvesting and processing of mixed algae biomass from an open pond

Final IDEA+ event, September 2023

Sandra Van Roy, Filip Vanhoof, Hans Sterckx, Bert Van den Bosch, Queenie Simons, Jef Verheyden, Leen Bastiaens – **VITO (Belgium)**

Paul Van Elslande, Dimitri Overmeire – **Yara (The Netherlands)**

Harvesting algae from open pond

Does MAF-technology offer a solution for the harvest needs?

Open pond cultivation:

- One 100 m³ pond
- 10-25% daily harvest → 10-25 m³/day
- Input concentration 0,1-1 g/L

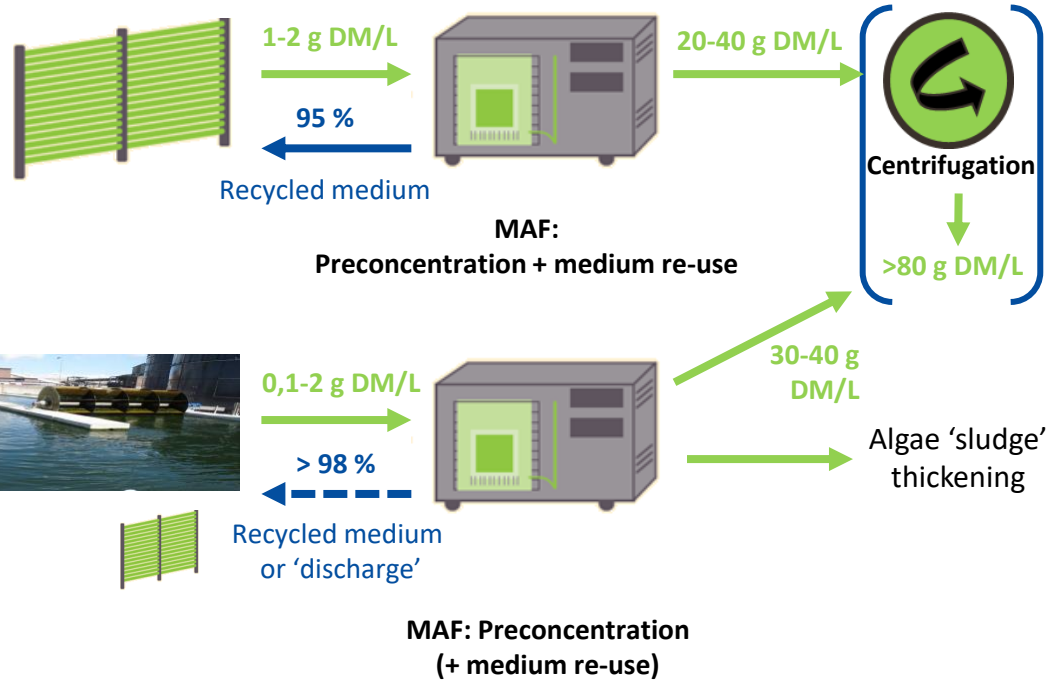
→ Large volumes
Low density

Potential harvesting approaches:

- Centrifugation → not cost/energy-efficient
- Flocculation
- Membrane filtration → MAF-technology

VITO MAF-technology
= Membrane Algae Filtration

- Submerged membranes – low shear
- Pre-concentration of algae (> 20 x)
- Medium recycling (>95%)
- Continuous harvest



Step 1: Can MAF-technology harvest mixed algae biomass from open pond?

Off-site MAF trials

Different batches (harvest numbers)	Season	Algae culture (L)	DM; OM (T0)52 (%)	Duration (days)	VCF reached	Fluxes	desalting
Test 1: Sept 2021	Autumn	216	low	1-2	21	OK	
Test 2: Jan 2022	winter	1967	Low	2	236	70-40 L/m²/h	
Test 3: March 2022	Early Spring	4400	low	2	> 63	70-34 L/m²/h	x
Test 4: May 2022	Late spring	4300	low	2	52	45 → 35 L/m²/h	X (13,4 → 3,7 mS/cm)

Quantification challenging

Conclusions:

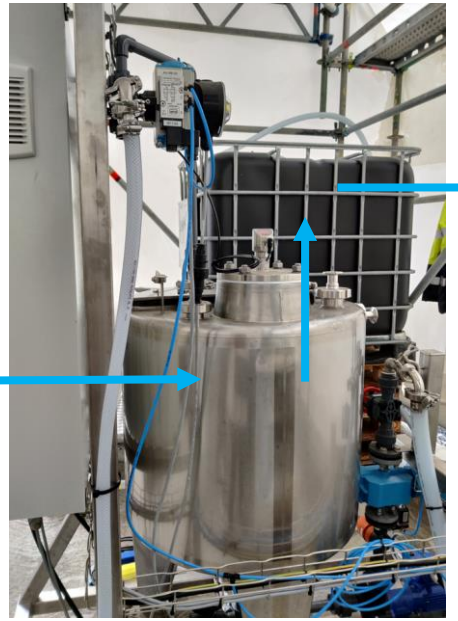
- Efficient dewatering with MAF
- Good fluxes
- Good upconcentration

MAF-permeate & algae biomass collected

Ready for on-site trials

Step 2: longer-term performance ?

Longer-term on-site MAF trials → set-up



Transport
to VITO

Step 2: longer-term performance ?

Long-term trial 1 – 70 days (September – December 2023

Phase	#days	Amount feed (L)	VCF	cleaning	out (L)	medium reuse (%)	flux (L/hm²)
Day 1-6	5	11879	84	x	125	98,9	98 --> 40
Day 6-8	2	5916	36		129	97,8	
Day 8-12 (2)	5	9090	64	x	253,5	97,2	30 --> 18
Day 12-15	3	5673	31		125	97,8	40 --> 18
Day 15-19	4	10242	71	x	129	98,7	44 -->20
Day 19-22	3	7943	53		127	98,4	
Day 22-26	4	9098	64		129	98,6	21 --> 21
Day 26-29	3	4569	47	x	129	97,2	21 --> 21
Day 29-35	6*	16036	80		129	99,2	21 --> 21
Day 35-40	5	6306	44		129	98,0	21 --> 18
Day 40-42	2	4428	30	x	129	97,1	21--> 21
Day 42-48	6	14287	98		129	99,1	21 --> 21
Day 48-51	3	7498	51		129	98,3	21 --> 21
Day 51-54	3*	3783	26		129	96,6	21 --> 21
Day 54-58	4	9859	68		129	98,7	35 --> 21
Day 58-61	3	6677	46		129	98,1	21 --> 21
Day 61-64	3	7553	52		129	98,3	21 --> 21
Day 64-68	4	6944	48		129	98,1	21 -->12
Day 68-70	2	3391	23	x	129	96,2	12 --> 15
total	**70**	**151172**			**2565,5**	**98,3**	

Day 1 = 29/9/2022; Day 70 = 7/12/2022

Biomass collection

More biomass collected than expected based on off-site trials

Focus on robustness & reliability

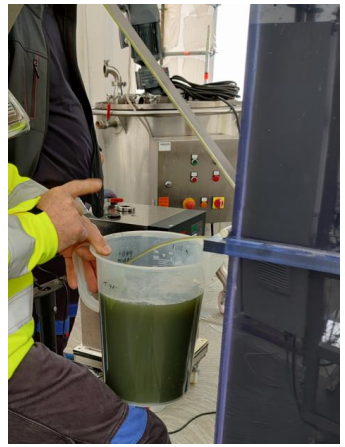
- Stable flux
- Maintenance reduction
- Operation at low temperature
- Clear MAF permeate

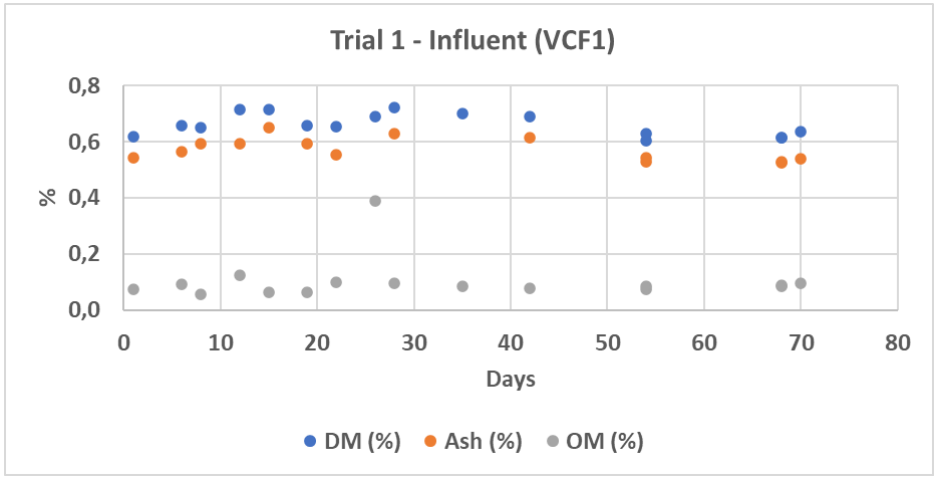
Step 2: longer-term performance ?

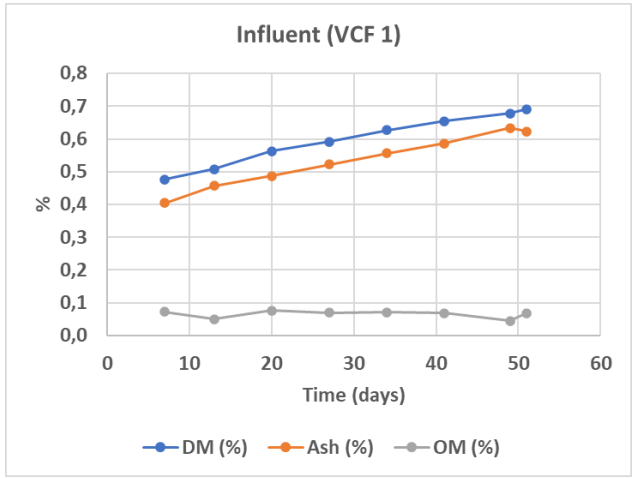
Longer-term on-site MAF trials → 50 days trial (1-3/2023)

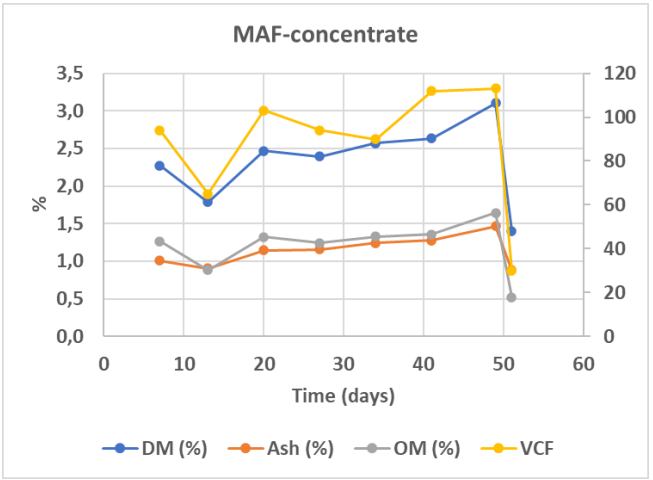
Phase	#days	Amount feed (L)	VCF	cleaning	out (L)	medium reuse (%)	flux (L/hm²)	kg DM
Day 0				x				
Day 1-7	6	12962	94		129	99,0	21 --> 21	2,39
day 7-13	6	7465	65	x	129	98,3	18 --> 12	1,64
Day 13-20	7	14213	103		129	99,1	21 --> 18	2,49
Day 20-27	7	12979	94	x	129	99,0	21 --> 18	2,57
Day 27-34	7	10847	90		129	98,8	21 --> 21	2,42
Day 34-41	7	15524	112		129	99,2	32 --> 21	2,6
Day 41-49	8	15678	113		129	99,2	21 -->18	3,25
Day 49-50	2	3961	30	x	129	96,7	21--> 18	0,83
Total	**50**	**93629**			**1032**	**98,9**		**18,19**

Day 1 = 11/1/2023; Day 51 = 02/03/2023







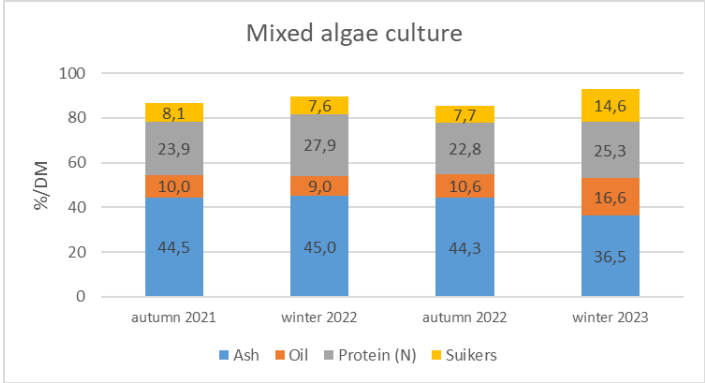


Two MAF-outputs

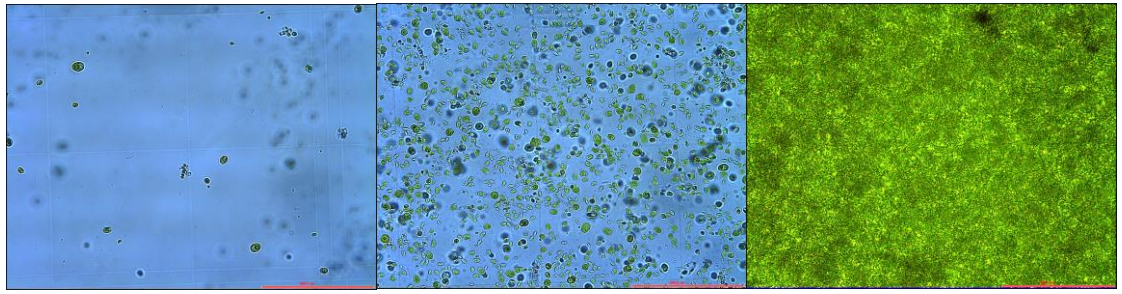
Algae biomass

- Collected amount: ≈ 30 kg DM
- Composition: seasonal fluctuations

2-9 % fatty acids
- C16:1
- C16:0
- EPA



- Application:
  - IDEA: Further dewatering (centrifuge) → freeze-drying → application testing
  - Discharge



MAF-permeate

- Composition (av. 7 time points)
  - DM: 0,57 ± 0,14 % pH: 7,3 ± 0
  - OM: 0,04 ± 0,03 % EC: 10,5 ± 2,7 ms/cm
  - Ash: 0,54 ± 0,16 %
  - N content: 11 – 50 (180)mg N/L (mostly nitrate)
  - Element analyses: constant trends; fluctuation in concentrations

	Ca	Co	Cu	Fe	K	Mg	Mn	Mo	Sb	Sr	Zn	P	S	Na
	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	
1	935000	6,2	12,3	<25	107000	117000	77,2	35,2	<10	3120	146	246	285000	
2	381000	<5	27.5	41.8	42200	43800	23.2	13.6	<20	1220	181	<75	109000	
3	770000	<5	32	<50	98000	83000	10	23	<10	2700	56	86	250000	
4	1100000	<5	32	<50	120000	105000	15	26	<10	3500	111	<75	250000	
5	603000	<5	10	11	67000	48000	14	17	<10	2000	67	<75	150000	
6	599000	<5	13	32	67000	62100	11	15	<10	2080	46	<75	231000	1770000
7	454000	<5	11	<25	54200	47200	<5	15	<10	1580	35	<75	115000	833000

- Application:
  - Recirculation in pond
  - Discharge
  - Higher value algae cultivation → IDEA

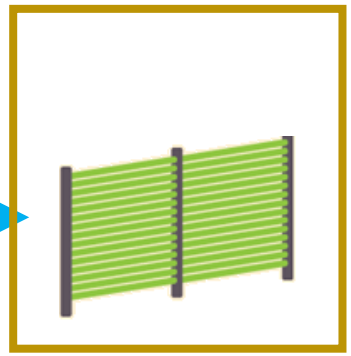
Takehome messages

- Yes, MAF is suitable to dewater mixed algae biomass from the open pond
- Long-term performance was demonstrated
- Maintenance manageable – Further automatization can reduce required efforts

- To be investigated:
  - impact of the harvesting approach on the algae production yield & N-removal capacity in the pond
  - An improved yield is expected.

Clear MAF permeate

Storage MAF permeate



Algae Cultivation on process water from a demineralization plant

Final IDEA+ event, 28 September 2023

Floris Schoeters – Thomas More Radius

Algae Cultivation on process water from a demineralization plant

Chloromonas typhlos

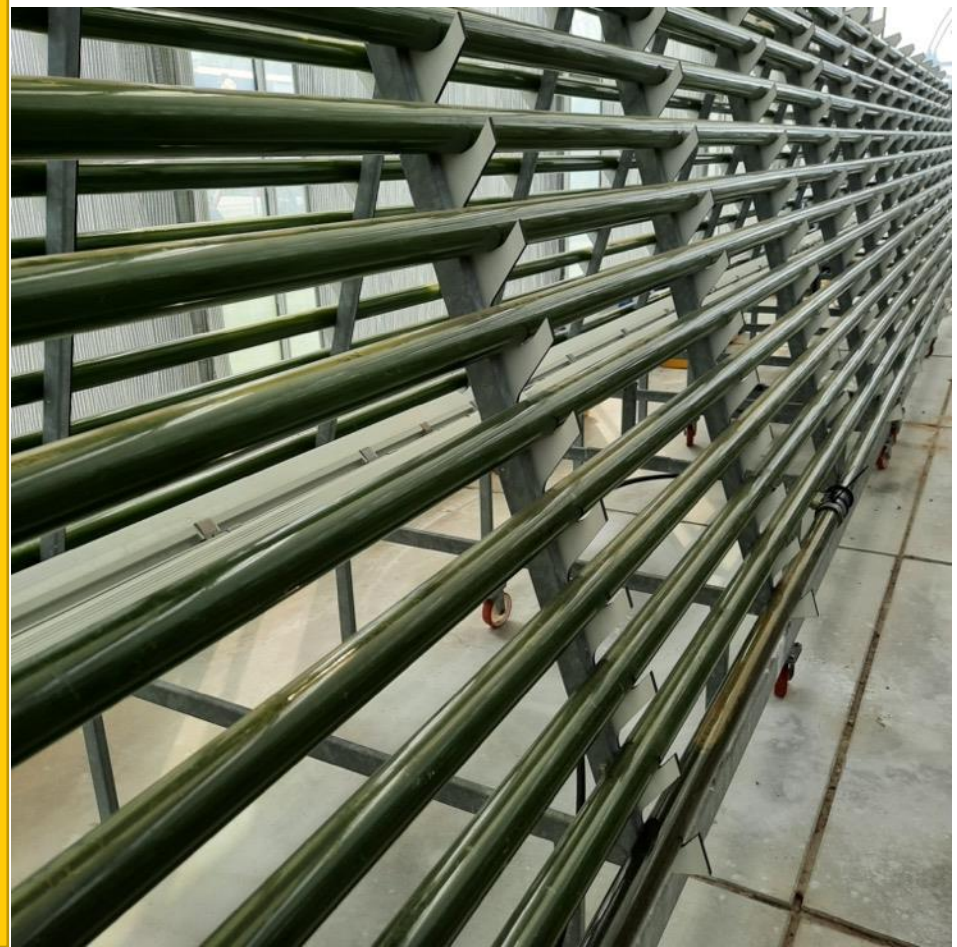
Porphyridium purpureum

Nannochloropsis gaditana

Acutodesmus obliquus
Chlorella sorokiniana
Desmodesmus armatus

Can you cultivate algae on on process water from a demineralization plant?

Nannochloropsis gaditana



YES!

Chloromonas typhlos

Results

- *N. gaditana*
  - Growth rates: 0.12-0.19 d^{-1} *(0.4 in regular medium in our system)**
  - Final DW: ± 1 g/L

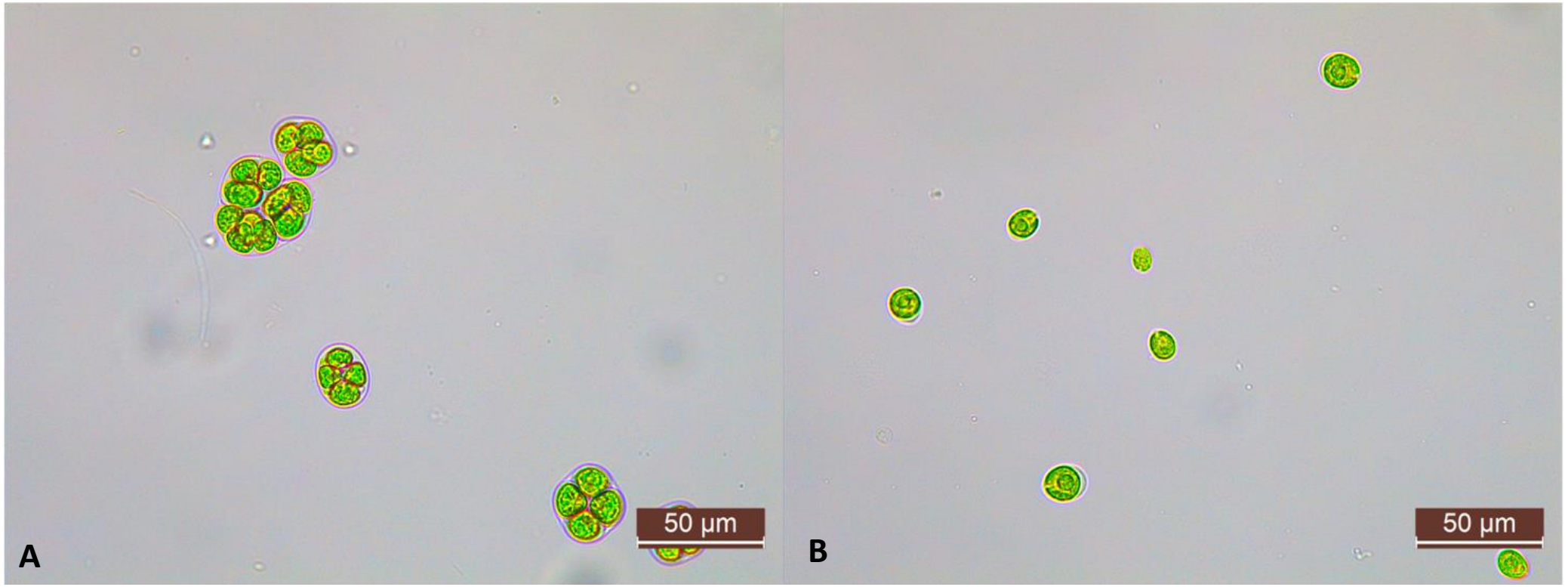
- *C. typhlos*
  - Growth rates 'warm' weather: 0.14-0.17 d^{-1} (*C. typhlos* is a winter algal species) & during wintertime: 0.092-0.12 d^{-1} *(0.02 - 0.11 in regular medium in our system)*
  - Final DW: ± 0.8 g/L (often at lower DW harvested)

Some examples

Foam in degasser unit: in process water always foam (left), in ‘regular’ medium (tap water) no foam (right)

Some examples

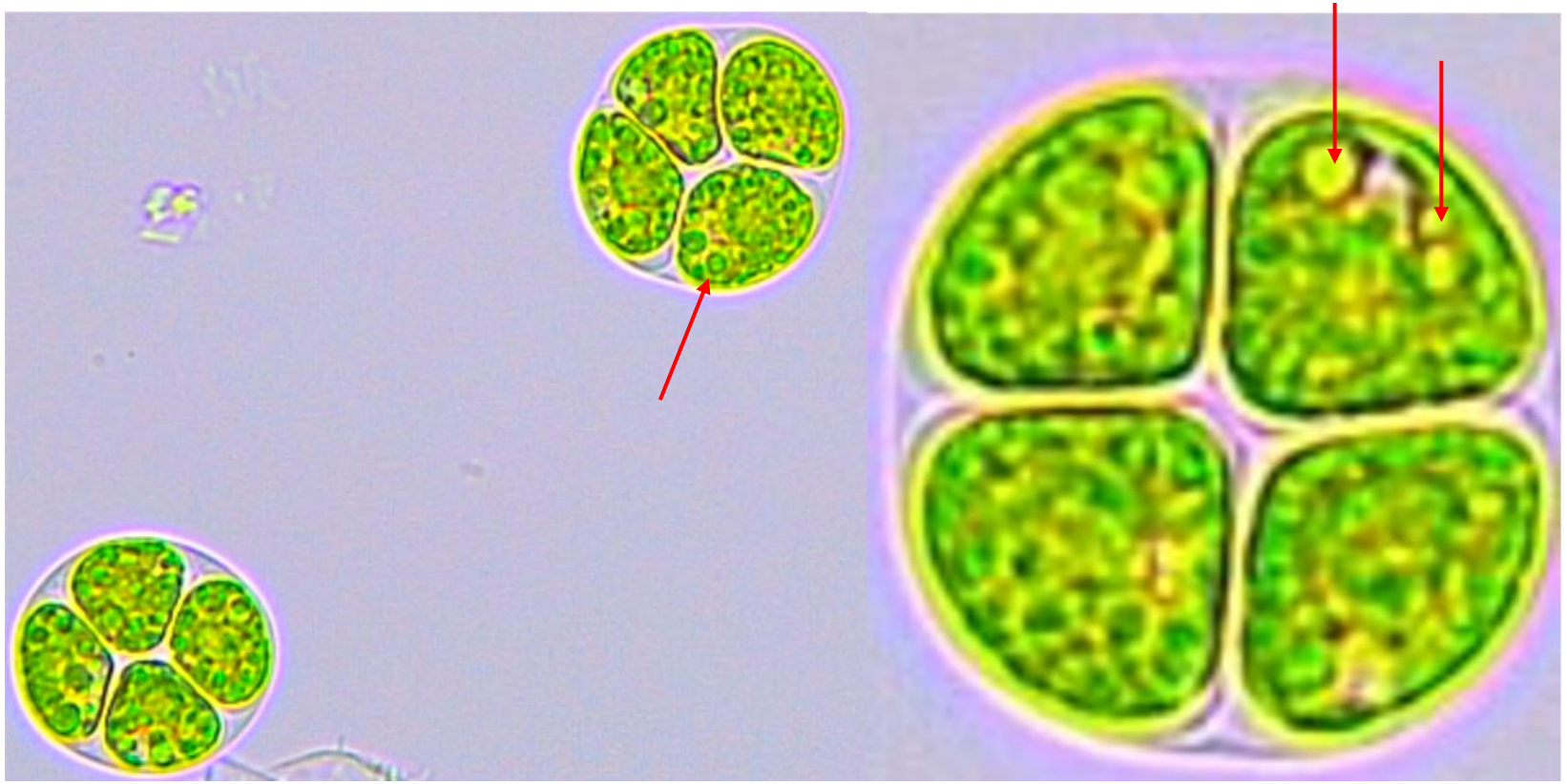
Morphology cells often different in process water (left) versus regular medium (tap water)



A) Process water; B) Regular (tap water based) medium

Some examples

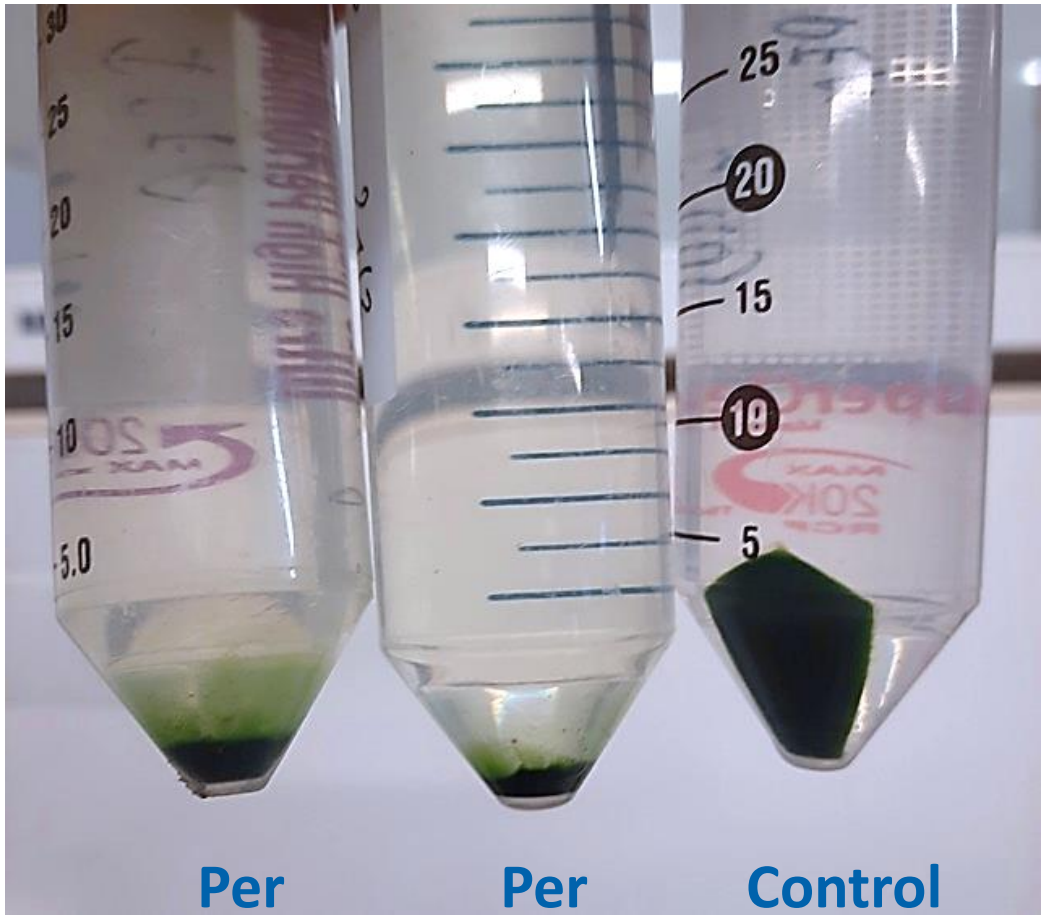
Morphology cells often different in process water: lipid globules formed



Lipid globules (‘circles’ inside cells) are formed when *C. typhlos* is cultivated in process water

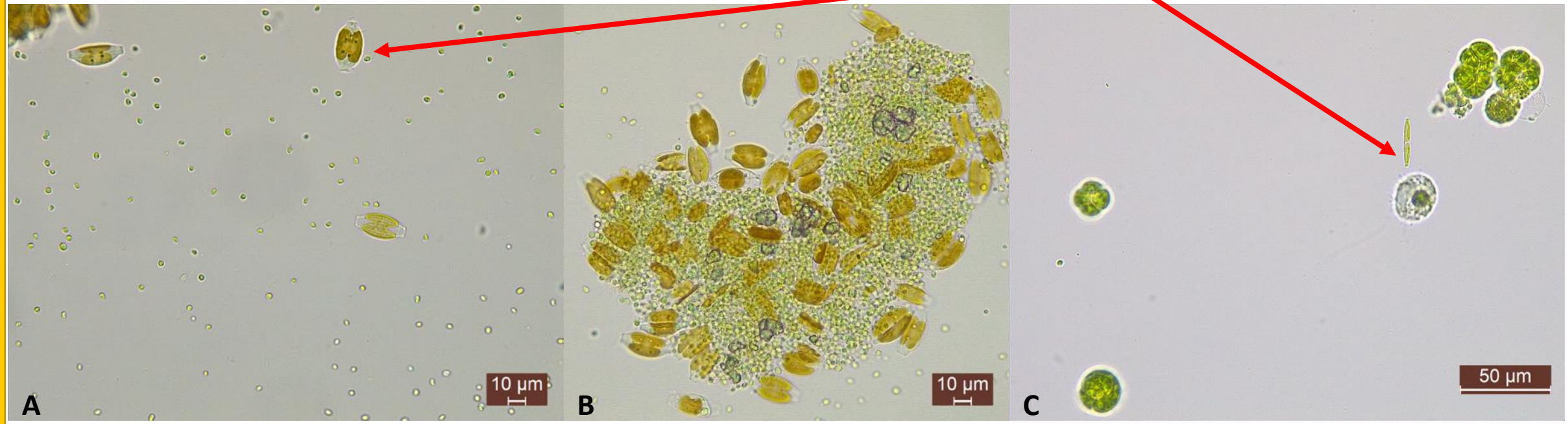
Some examples

Not only morphology, but also behavior of cells/characteristics ‘medium’ often different in process water: samples after centrifugation



Some examples

No filtration prior to usage (left)* versus filtration prior to usage (right)
(process water already filtered with MAF before storage) => contamination



A) start of growth diatom (contamination); B) after a while a lot (especially in the foam); C) in filtered process water, spotted after a month and you must look for it

Key messages

It can be done!

Using process water (or '*side streams*' in general) lowers the footprint and increases the sustainability. However, complexity increases.

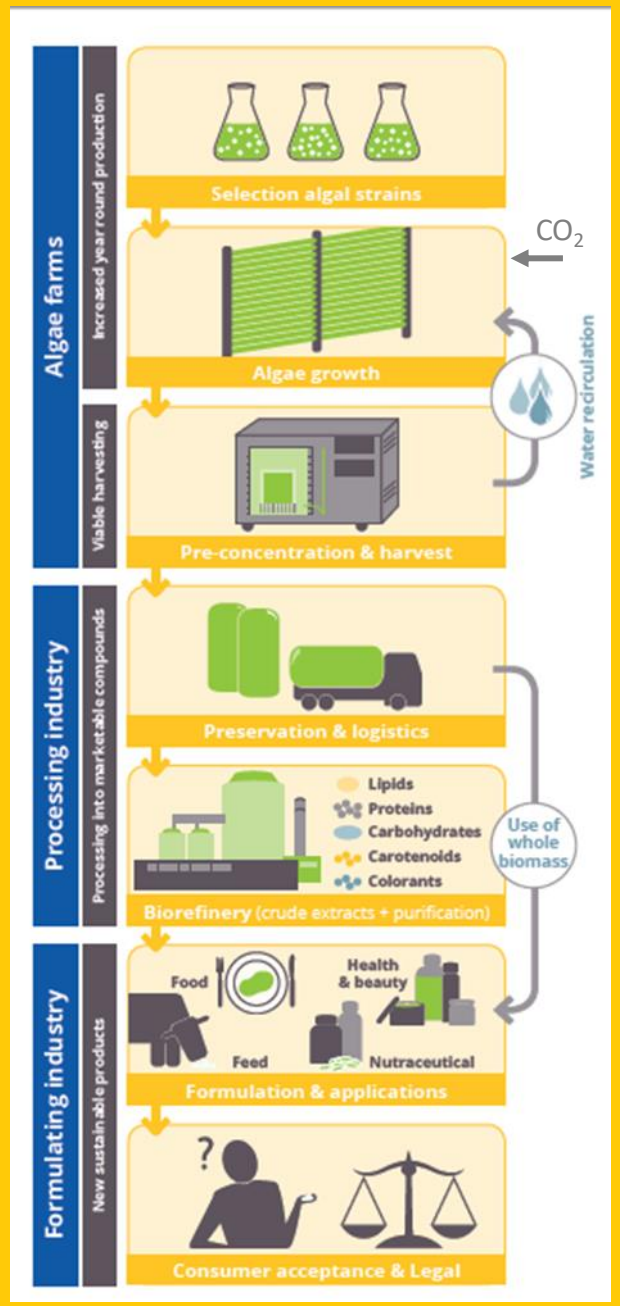
- Knowledge of process water is essential => chemical analysis

- Extra filtration step prior to usage => (extra) 0.5 and 0.2 μm filtration

- More tests needed: larger scale tests (e.g., foam, morphology & behavior of cells, evaluation of biomass)

- Legal hindrances (?)

- Lab scale =/= pilot- or large-scale



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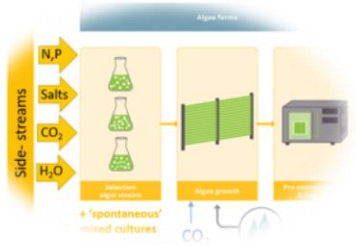
Yara Sluiskil: Dimitri Overmeire, Paul Van Elslande

All other partners



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Website: www.nweurope.eu/idea

Full partners: