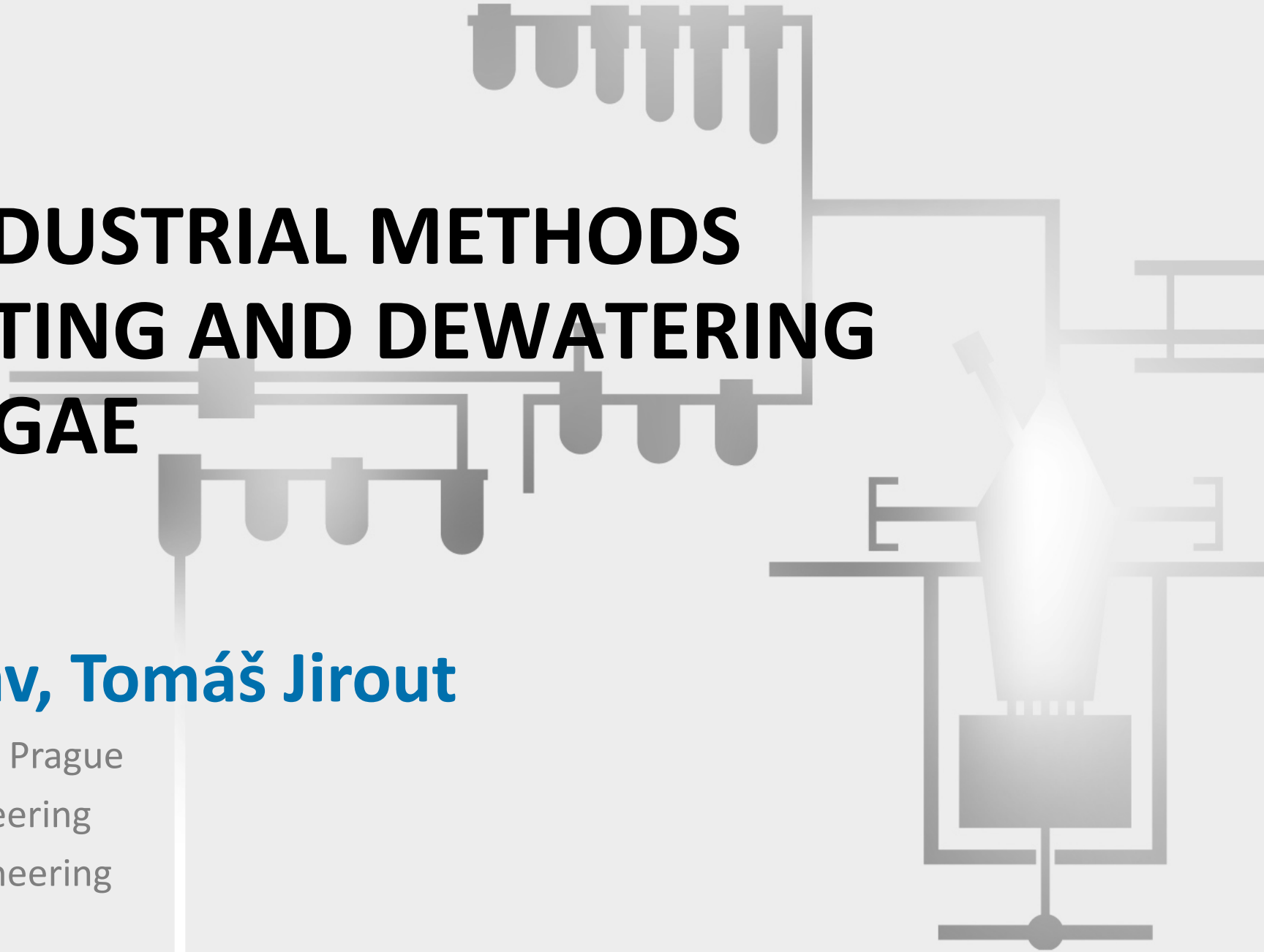
FACULTY
OF MECHANICAL
ENGINEERING
CTU IN PRAGUE

DEPARTMENT OF PROCESS ENGINEERING

EFFICIENT INDUSTRIAL METHODS FOR HARVESTING AND DEWATERING OF MICROALGAE



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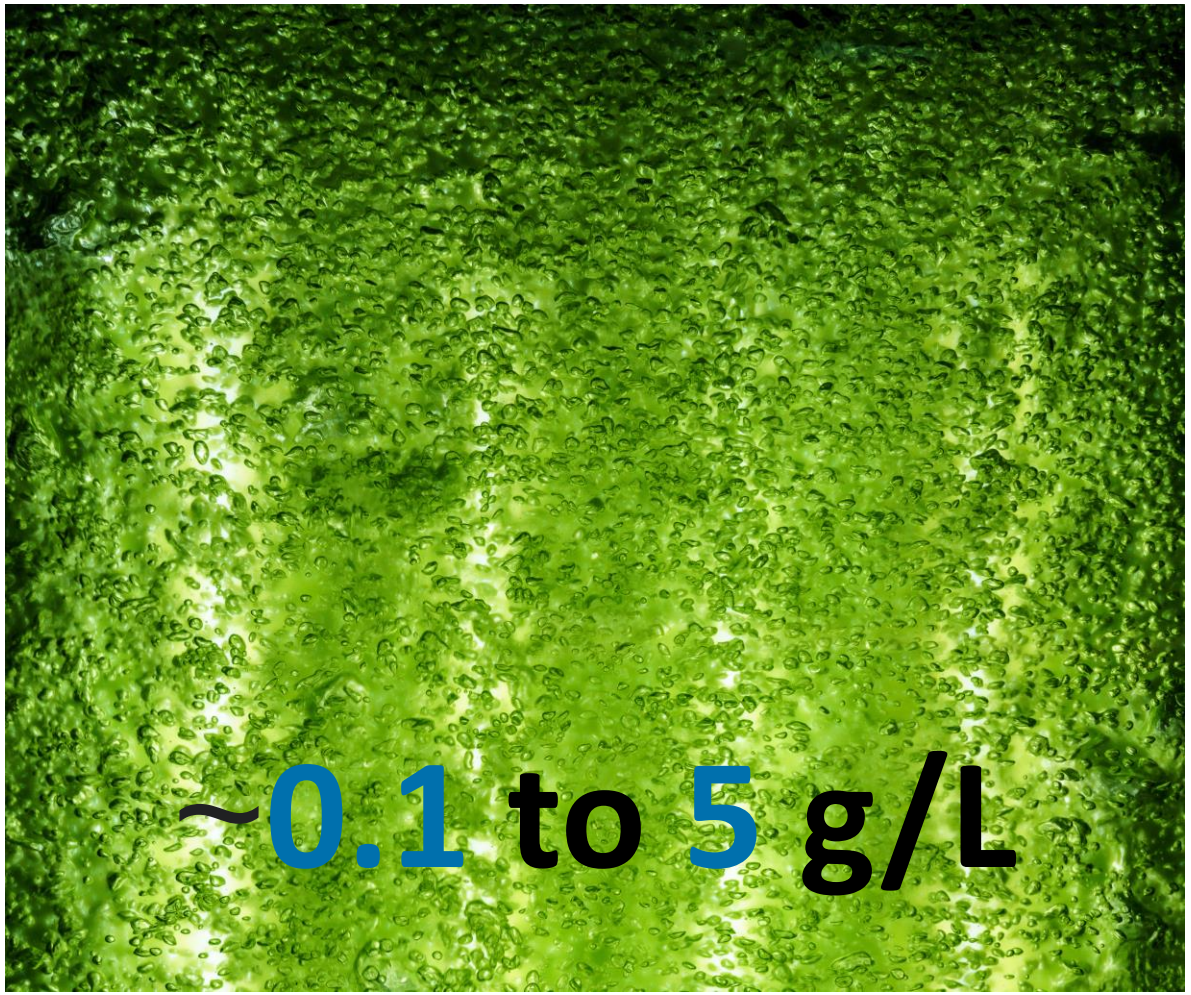
Microalgae | Harvesting and Dewatering



Microalgae | Harvesting and Dewatering

Biomass production cost

30 %

CAPEX

Closed systems

33 %

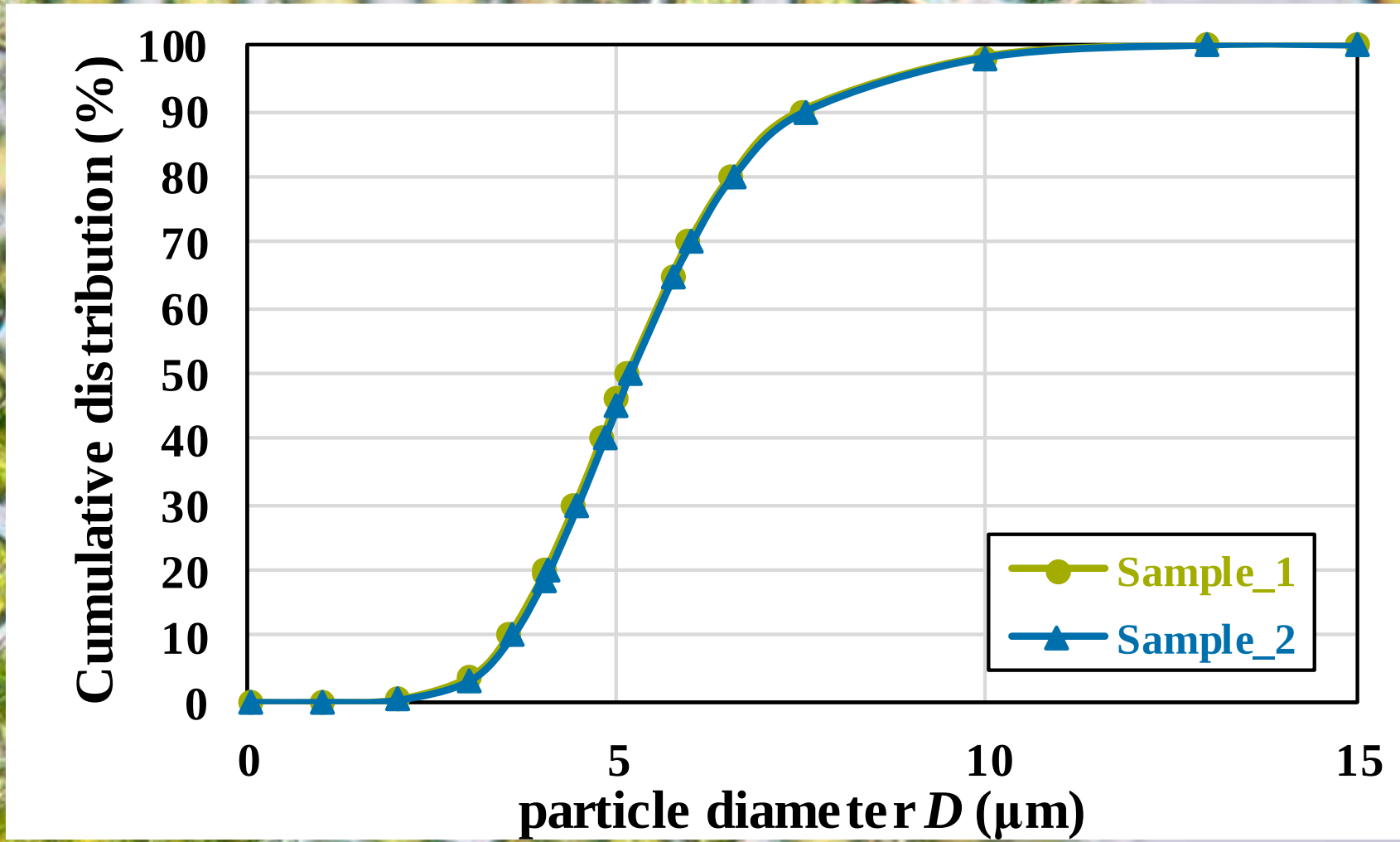
CAPEX

Open systems

90 %

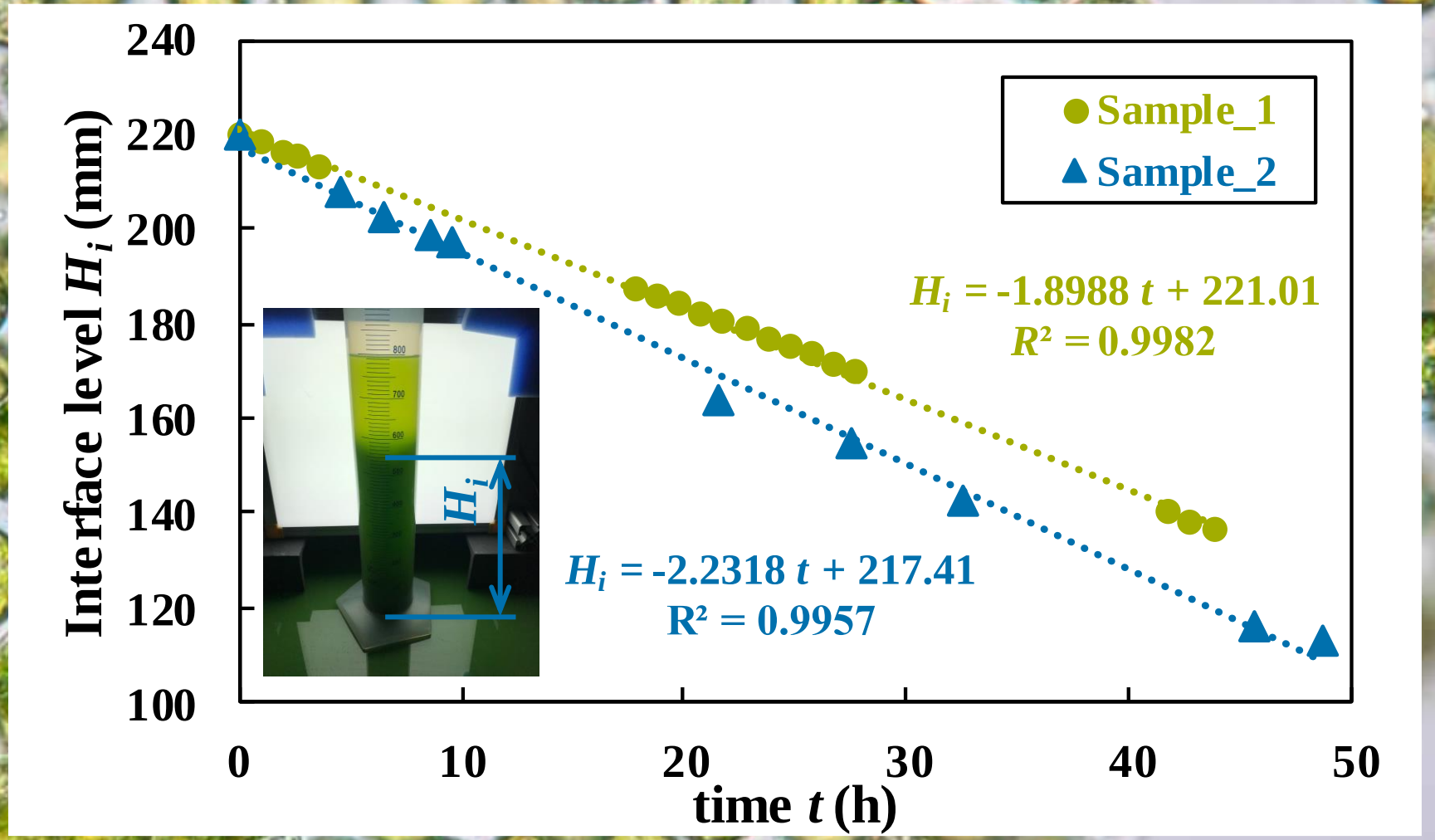
Microalgae | Properties

Sample	1	2
Algae concentration X_b (g L^{-1})	1.1	1.7
Mean cell diameter D_{50} (µm)	5.12	5.19



Microalgae | Properties

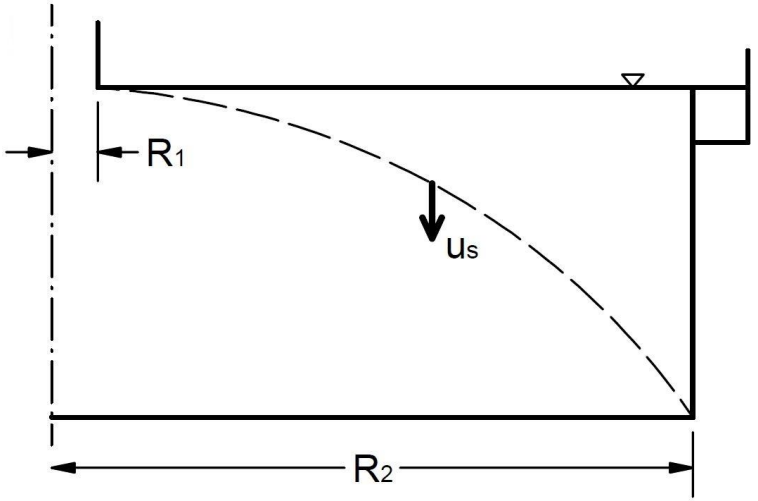
Sample	1	2
Algae concentration X_b (g L^{-1})	1.1	1.7
Mean cell diameter D_{50} (µm)	5.12	5.19
Settling velocity u_s (mm h^{-1})	1.8	2.3



Model cultivation technologies

Technology built-up area (ha)	Processed culture medium ($m^3\ h^{-1}$)
0.2	0.3
1	10
100	250

Harvesting | Circular settler



$A_{built-up}$ (ha)	R_1 (m)	R_2 (m)
0.2	0.05	7
1	0.05	40
100	0.05	200

Full separation | Processed suspension V_{su} ($m^3\ s^{-1}$)

$$V_{su} = \pi\, u_s \left(R_2{}^2 - R_1{}^2\right)$$

u_s - settling velocity of microalgae cells ($m\ s^{-1}$)

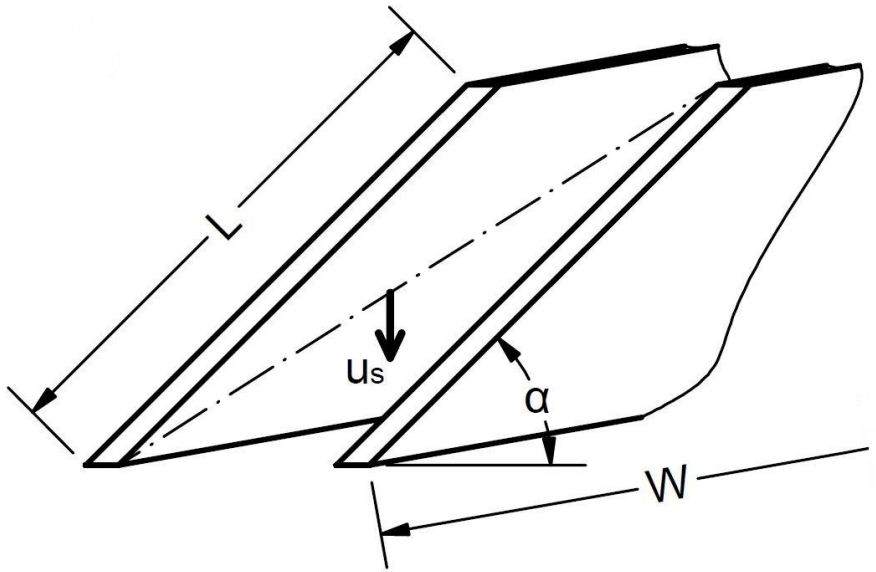
Thickening | Cross-sectional area of the settler A (m^2)

$$A = \frac{V_{su}\, X_{su}}{u_s}\left(\frac{1}{X_{su}} - \frac{1}{X_t}\right)$$

X_{su} - inlet suspension concentration ($g\ L^{-1}$)

X_t - outlet suspension concentration ($g\ L^{-1}$)

Harvesting | Lamella settler



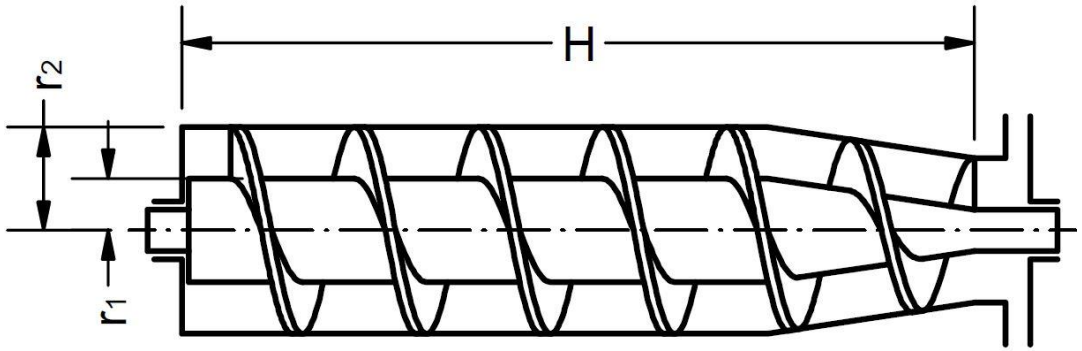
$A_{built-up}$ (ha)	L (m)	W (m)	i (-)
0.2	2.4	3	30
1	2.4	5	600
100	2.4	5	14 700

Full separation | Processed suspension V_{su} ($m^3\ s^{-1}$)

$$V_{su} = i\, u_s\, L\, W \cos \alpha$$

i - number of lamellae in settler (-)

Dewatering | Decanter centrifuge



Full separation | Processed suspension V_{su} ($m^3\ s^{-1}$)

$$V_{su} = \frac{\pi\, H\, D^2 \left(r_2^2 - r_1^2\right)\left(\rho_p - \rho_l\right)\left(2\pi \frac{n}{60}\right)^2}{18\mu\, \ln \frac{r_2}{r_1}}$$

D - diameter of microalgae cells (m)

n - rotation speed of the bowl (rpm)

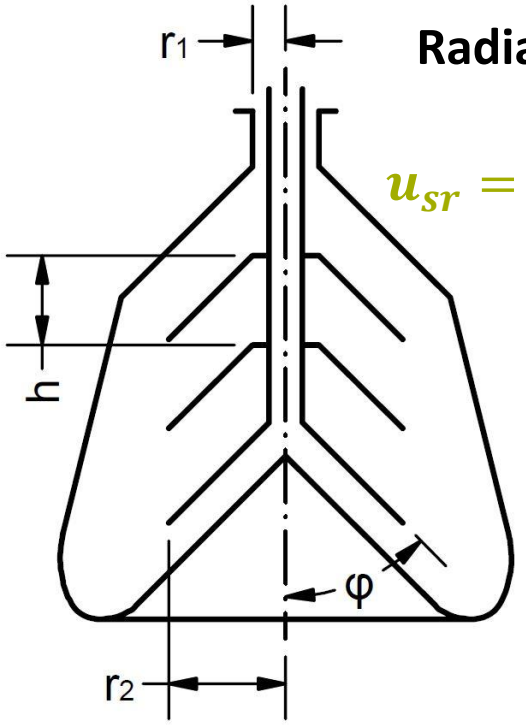
ρ_l - density of culture medium ($kg\ m^{-3}$)

ρ_p - density of microalgae suspension ($kg\ m^{-3}$)

μ - suspension dynamic viscosity (Pa s)

$A_{built\text{-}up}$ (ha)	r_1 (m)	r_2 (m)	H (m)	n (-)
0.2	0.050	0.100	0.7	2 500
1	0.120	0.225	2.3	3 300
100	N/A			

Dewatering | Disc centrifuge



Radial component of peripheral velocity

$$u_{sr} = 0.27\, u_{sg} \left(\frac{r_1}{r_2}\right)^{-0.397} \left(\frac{h}{r_2\, tan\, \varphi}\right)^{-0.957}$$

Settling velocity in centrifuge

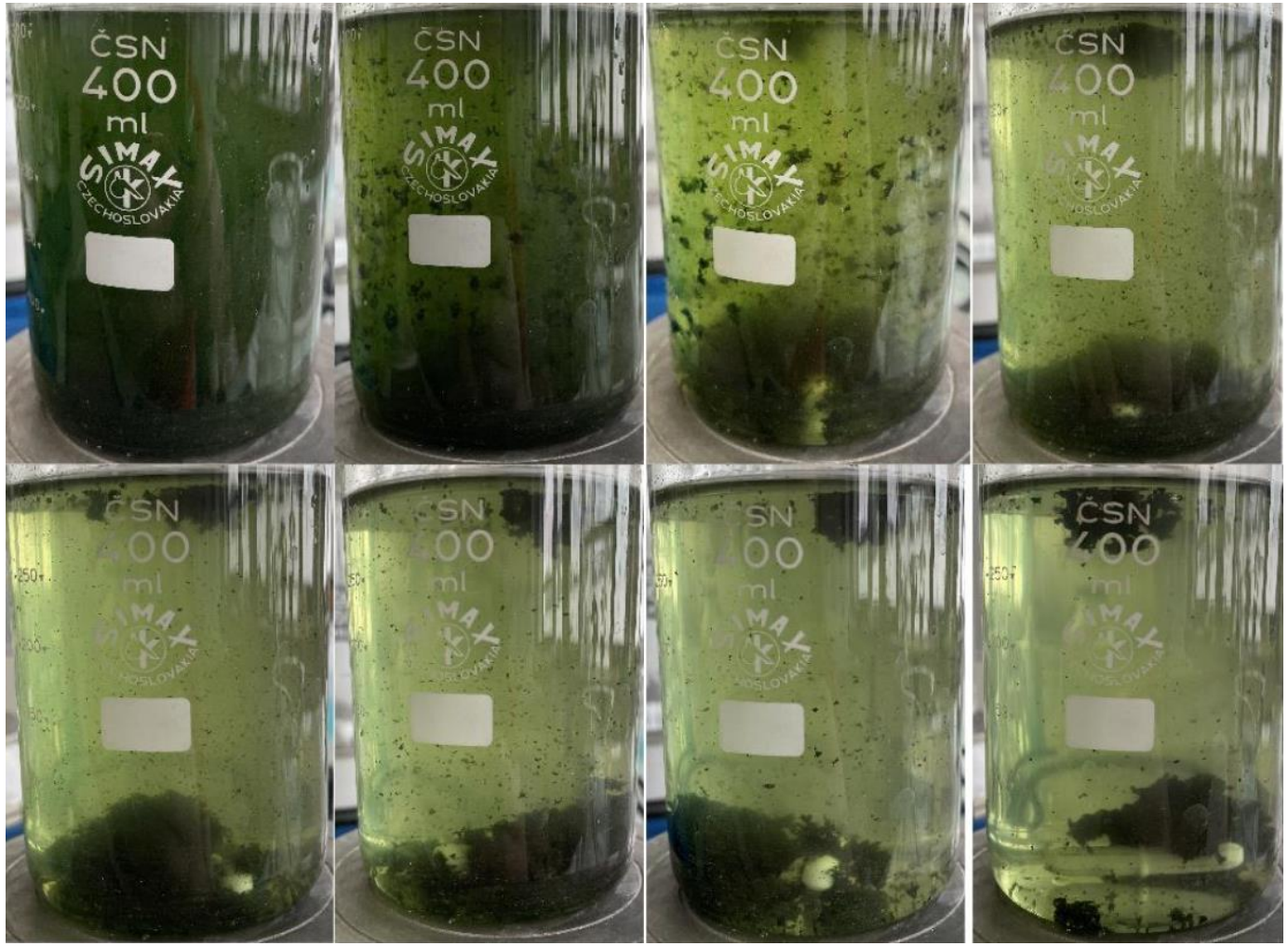
$$u_{sg} = r_2 \frac{D^2(\rho_p - \rho_l)\left(2\pi \frac{n}{60}\right)^2}{18\mu}$$

$A_{built\text{-}up}$ (ha)	r_1 (m)	r_2 (m)	n (rpm)	i (-)
0.2	0.064	0.125	1 500	20
1	0.064	0.125	3 900	82
100	0.12	0.400	3 000	87

Full separation | Processed suspension V_{su} ($m^3\ s^{-1}$)

$$V_{su} = i\, 2\, \pi\, r_2\, h\, u_{sr}$$

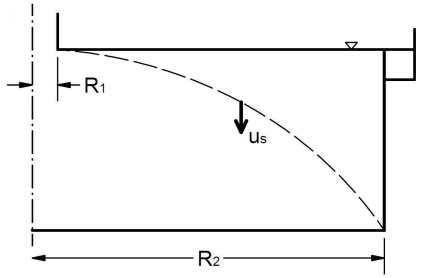
Flocculation | Sedimentation rate



Sample	Settling velocity (m h^{-1})	Microalgae concentration (g L^{-1})
Sample 1	$1.9 \cdot 10^{-3}$	1.1
Sample 2	$1.9 \cdot 10^{-3}$	1.7
PWG 54, 8.25 ml L^{-1}	3.0	1.1
PWG 54, 8.50 ml L^{-1}	4.8	
PWG 54, 8.75 ml L^{-1}	10.3	
PWG 54, 10.00 ml L^{-1}	18.0	

Flocculation | Harvesting and Dewatering

Circular settler

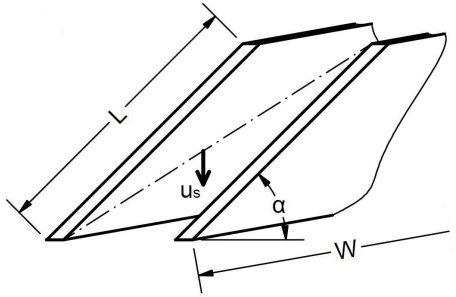


$A_{built-up}$ (ha)	R_1 (m)	R_2 (m)
0.2	0.05	7
1	0.05	40
100	0.05	200

Flocculation

100	0.05	4

Lamella settler

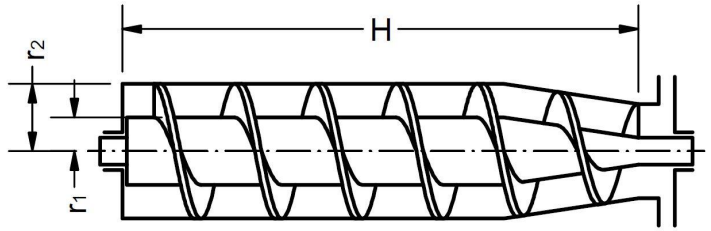


$A_{built-up}$ (ha)	L (m)	W (m)	i (-)
0.2	2.4	3	30
1	2.4	5	600
100	2.4	5	14 700

Flocculation

1	0.6	0.5	10
100	2.4	3	10

Decanter centrifuge

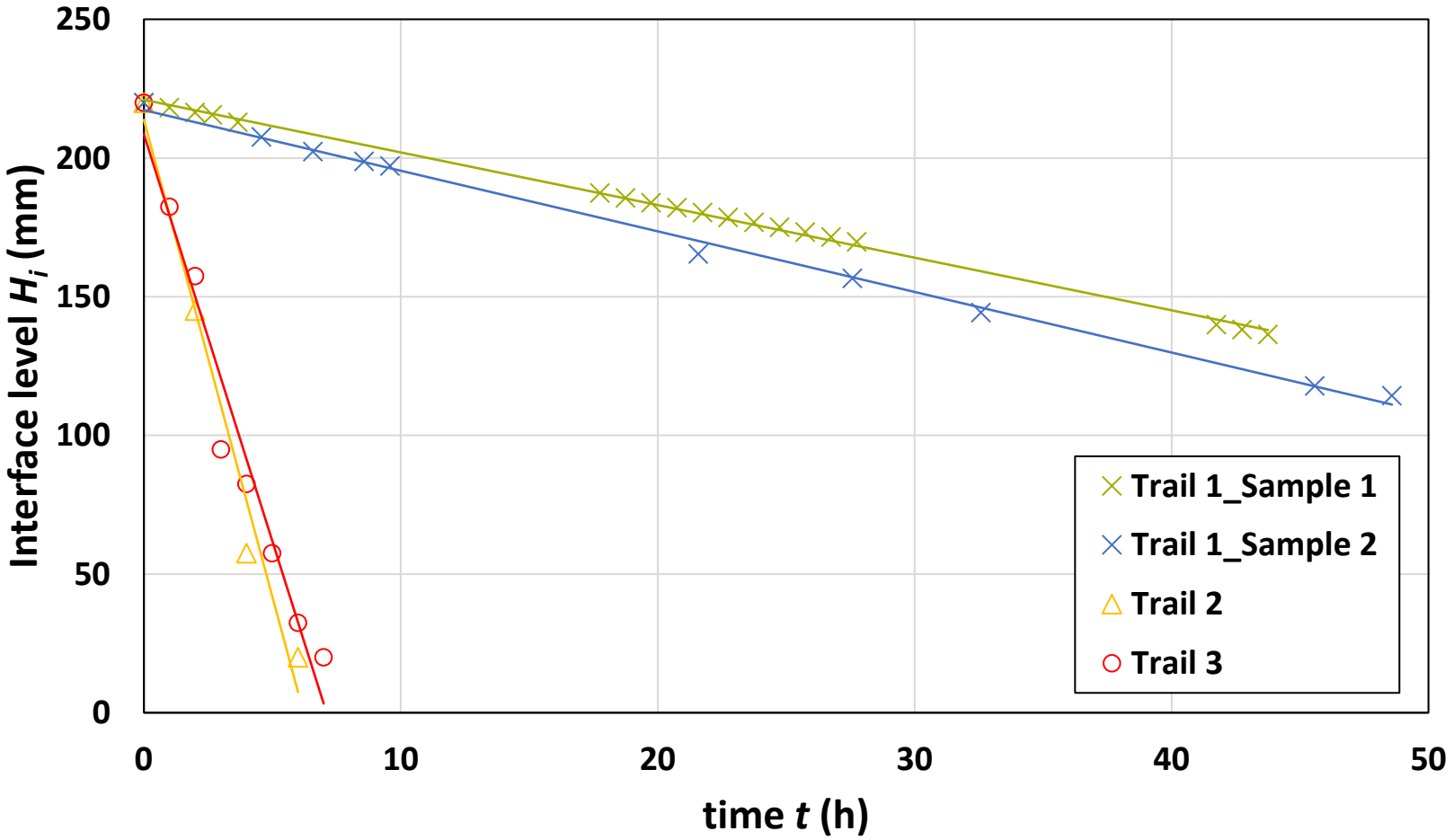


$A_{built-up}$ (ha)	r_1 (m)	r_2 (m)	H (m)	n (-)
0.2	0.050	0.100	0.7	2 500
1	0.120	0.225	2.3	3 300
100	N/A			

Flocculation

100	0.050	0.100	0.5	1 600

Microalgae | Sedimentation rate variation



Sample	Settling velocity (mm h^{-1})
Trail 1_Sample 1	1.8
Trail 1_Sample 2	2.3
Trail 2	45.3
Trail 3	32.5

Affecting parameters

???

Conclusions| Harvesting and Dewatering

Effective separation equipment design methodology

- Harvesting and Dewatering cost reduction
- Utilization for scale-up

Flocculation

- Promising separation method for industrial applications

Sedimentation rate variation

- Optimal characteristics of the culture medium for separation