
Control of *Thiothrix* bulking in a full-scale treatment plant with a sludge granulation strategy

Olivier Henriet

January 25, 2018

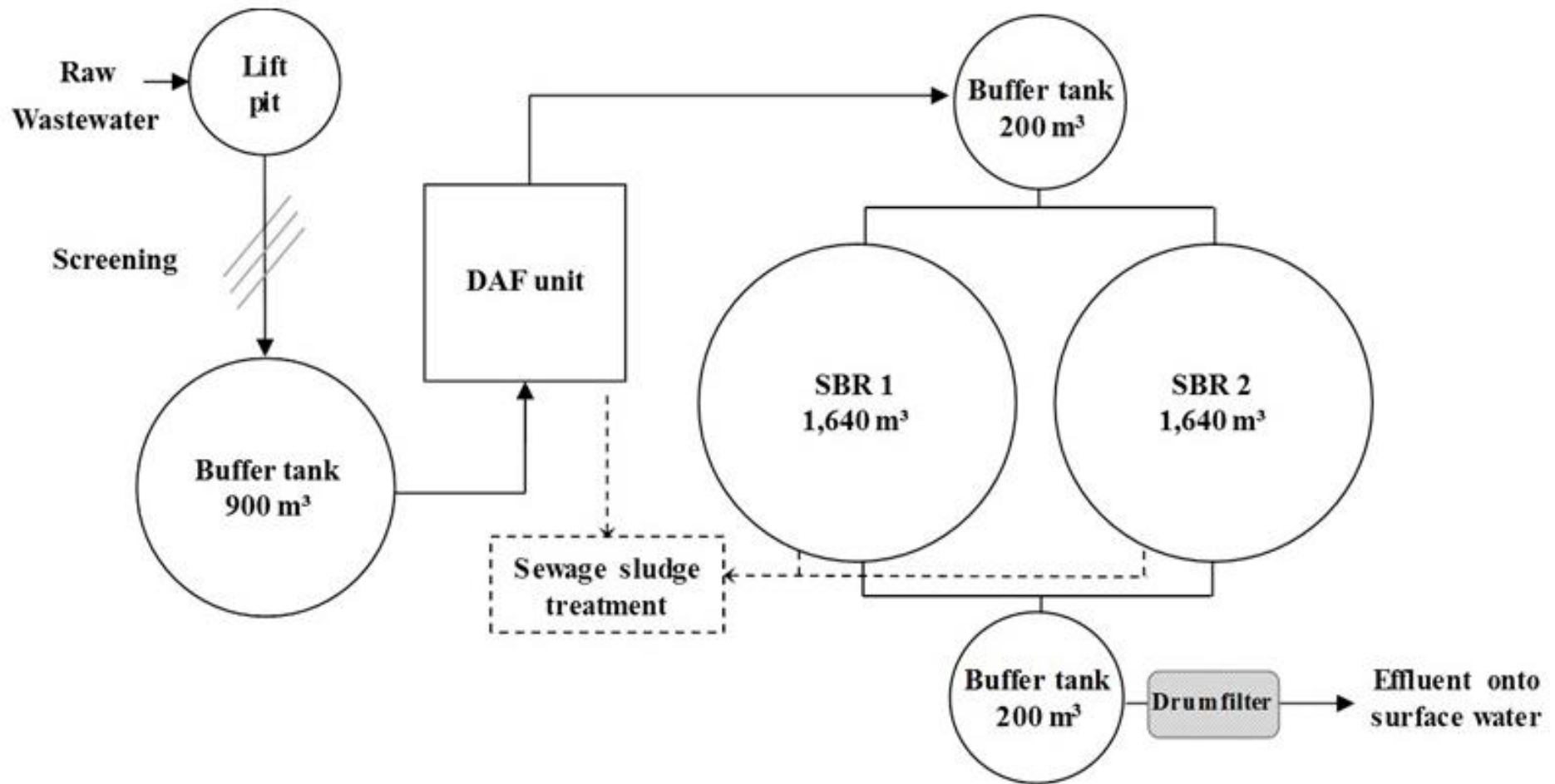
Dairy industry

Products

Milk
Cream
Ice Cream
Butter
Cheese
Yoghourt
Cookies



Full-scale plant



Henriet et al. 2017 Sci. Rep.

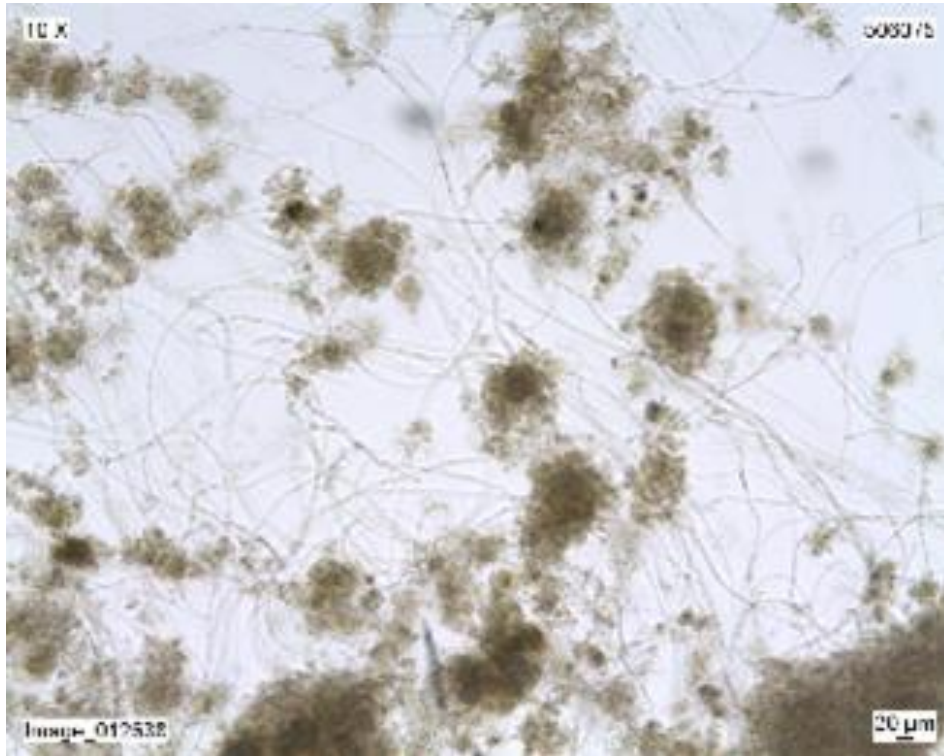
Full-scale plant



Pre-treated wastewater composition

Parameter	Mean (\pmSD)	Effluent discharge limits	Unit
Flow	870 (\pm 255)	-	m ³ day ⁻¹
Total COD	1358 (\pm 485)	110	mg L ⁻¹
Soluble COD	868 (\pm 447)	-	mg L ⁻¹
Total Nitrogen	55 (\pm 5)	15	mg L ⁻¹
Total Phosphorus	11 (\pm 5)	2	mg L ⁻¹
NH ₄ ⁺ -N (dissolved)	9 (\pm 13)	10	mg L ⁻¹
TSS	-	30	mg L ⁻¹
Temperature	24 (\pm 3)	-	°C
pH	7.6 (\pm 0.2)	-	-

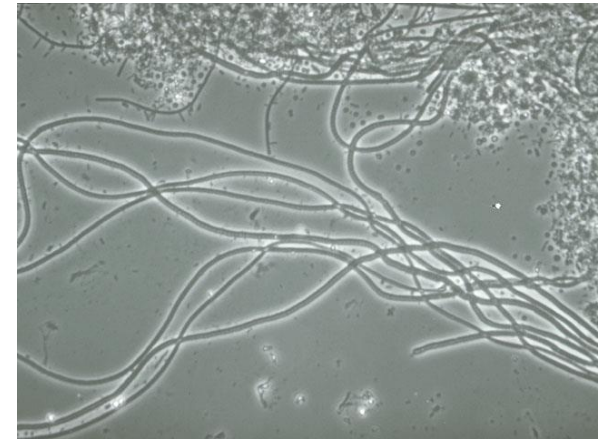
Filamentous bulking caused by *Thiothrix*



Thiothrix

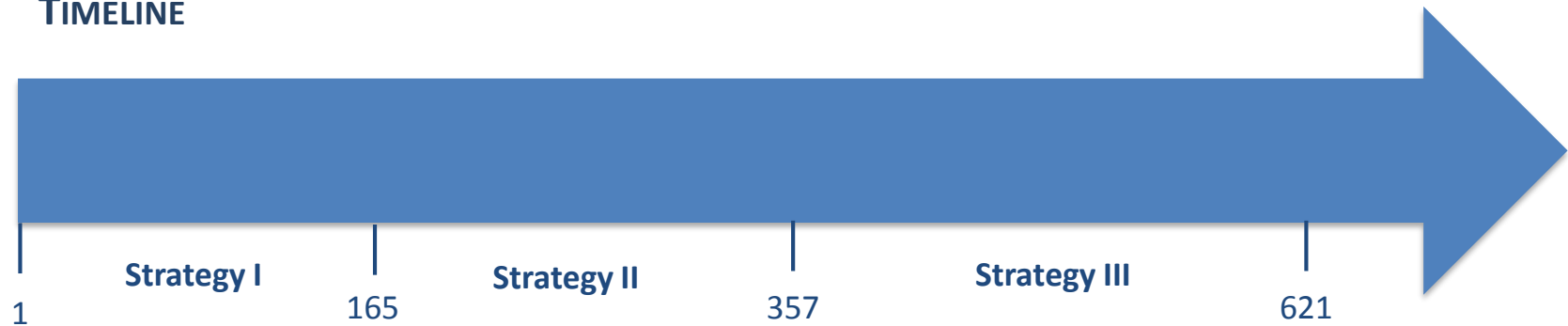
Abundance up to 70%

Reccuring problem



Treatment strategies

TIMELINE



Conventional process

Aerobic feeding

Polyaluminum chloride
addition

Conventional process

Aerobic feeding

Inhibition of VFA
production

Granulation process

Un aerated feeding

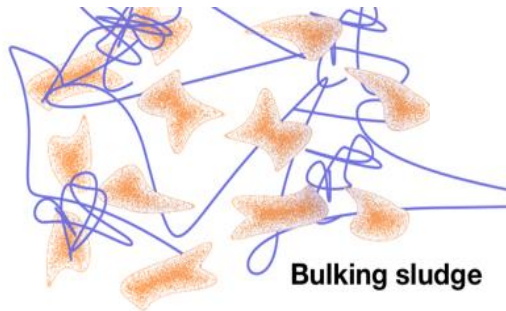
Metabolic selection

→ **Sludge densification**

Create a competition for the substrate

**Acetate
Propionate**

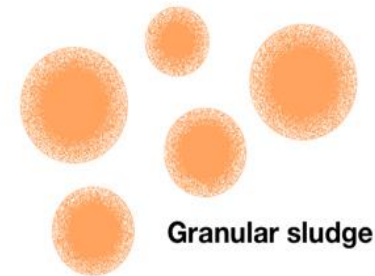
Aerated conditions



Bulking sludge

Filamentous bacteria

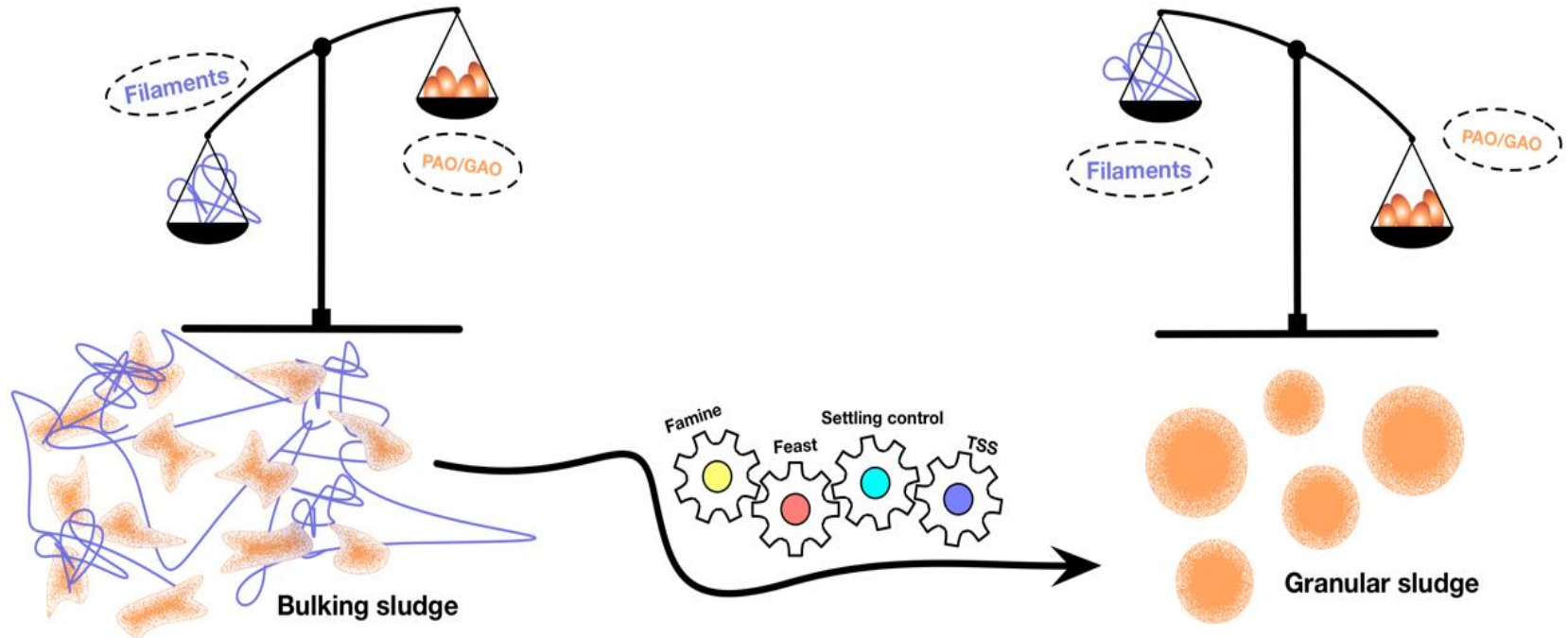
Non-aerated conditions



Granular sludge

**Biopolymer accumulating
bacteria**

Create a competition for the substrate

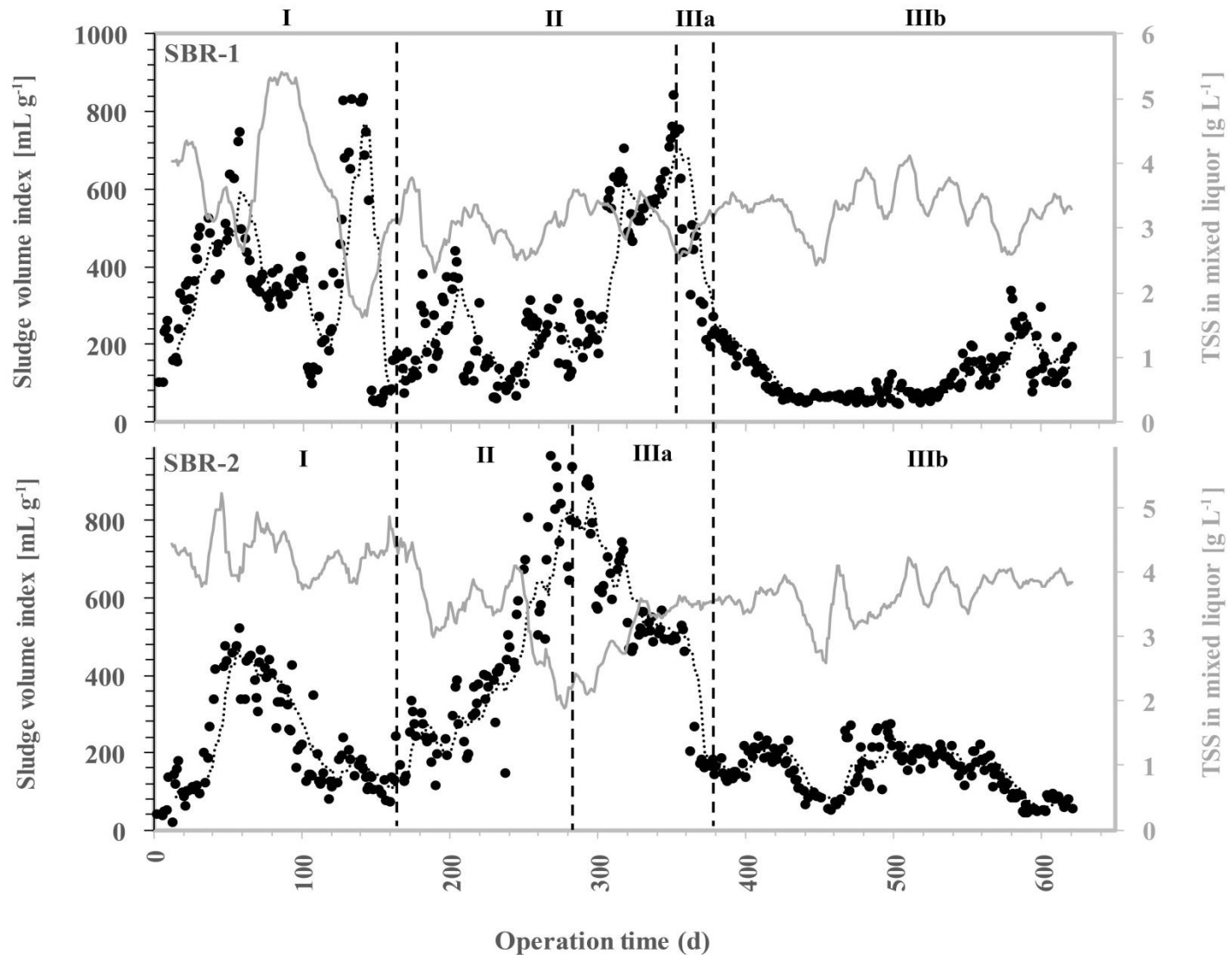


Meunier et al. 2016 *Bioresource Technol.*

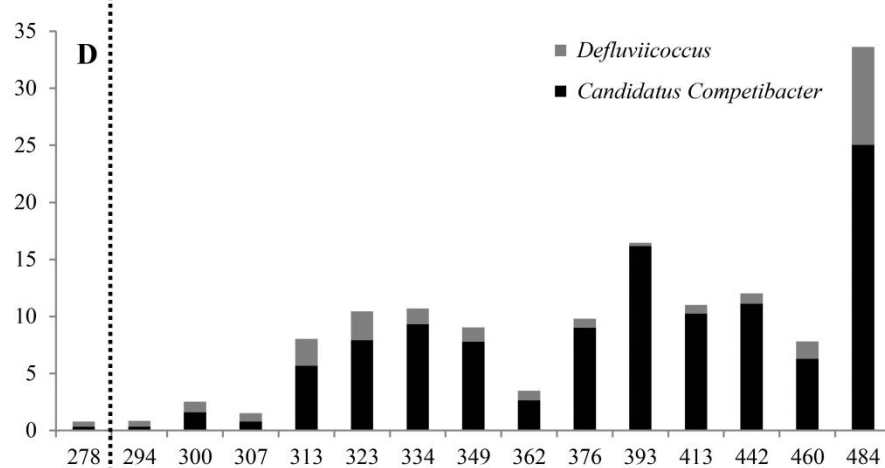
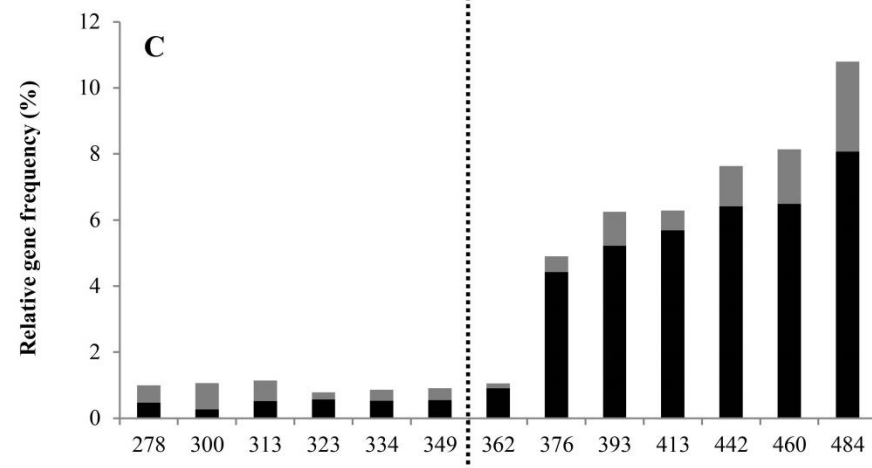
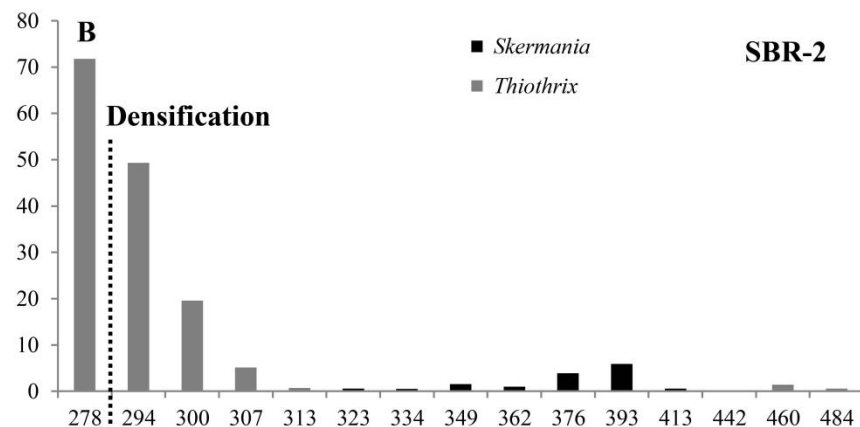
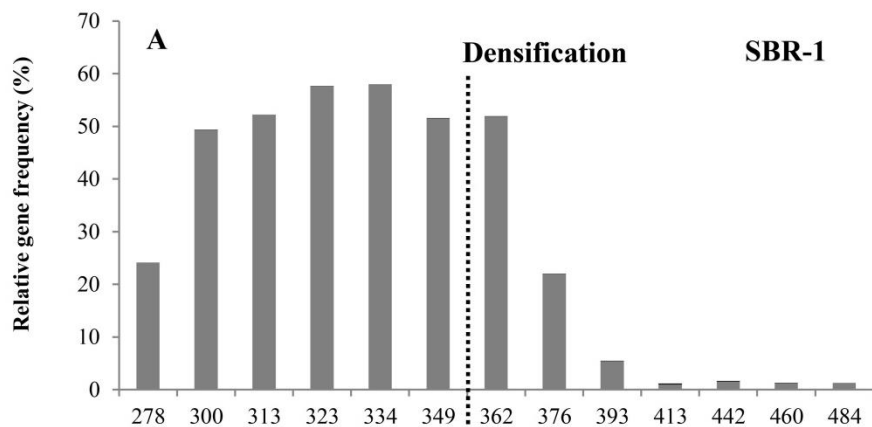
Operational parameters

SBR-1	Strategy		I	II	IIIa	IIIb
	Days		1-165	166-357	358-384	385-621
	Buffer tanks					
	Mixing with aeration		No	Yes	Yes	No
	Cycle					
	Aerobic feed	min		120		0
	Anaerobic feed	min		0		95
	Aeration	min		190		210
	Settling	min		50 - 60		40
	Decanting	min		110		115
	Sludge purge and idle	min		10		20
SBR-2	Strategy		I	II	IIIa	IIIb
	Days		1-165	166-282	283-384	385-621
	Buffer tanks					
	Mixing with aeration		No	Yes	Yes	No
	Cycle					
	Aerobic feed	min		120		0
	Anaerobic feed	min		0		95
	Aeration	min		190		210
	Settling	min		50 - 60		40
	Decanting	min		110		115
	Sludge purge and idle	min		10		20

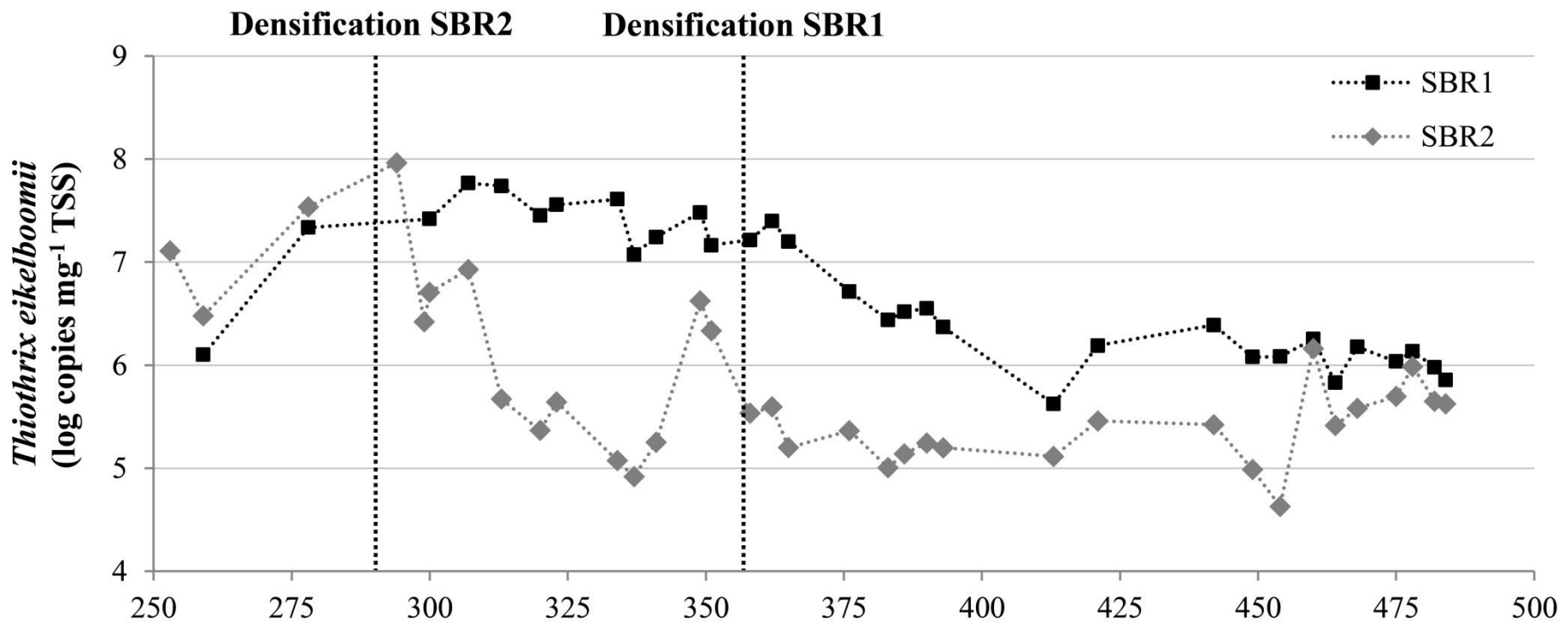
Sludge characteristics



Impacts on *Thiothrix* and accumulating bacteria



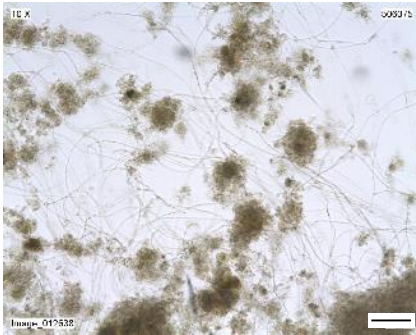
Impacts on *Thiothrix* and accumulating bacteria



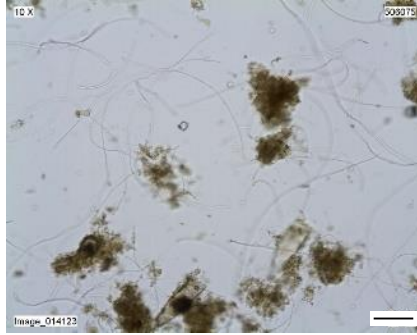
Evolution of the sludge

SBR-1

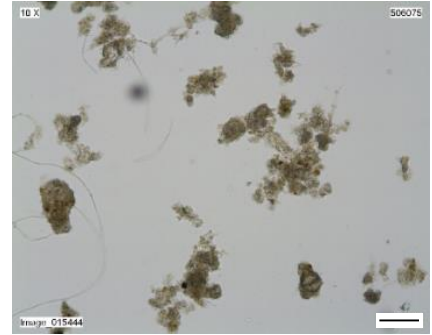
I



II



III

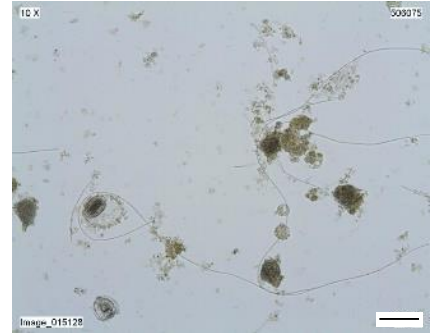
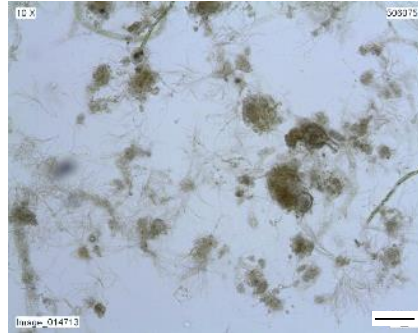
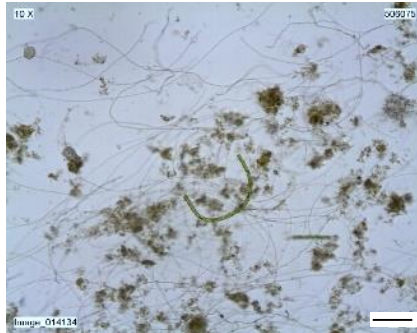


SBR-2

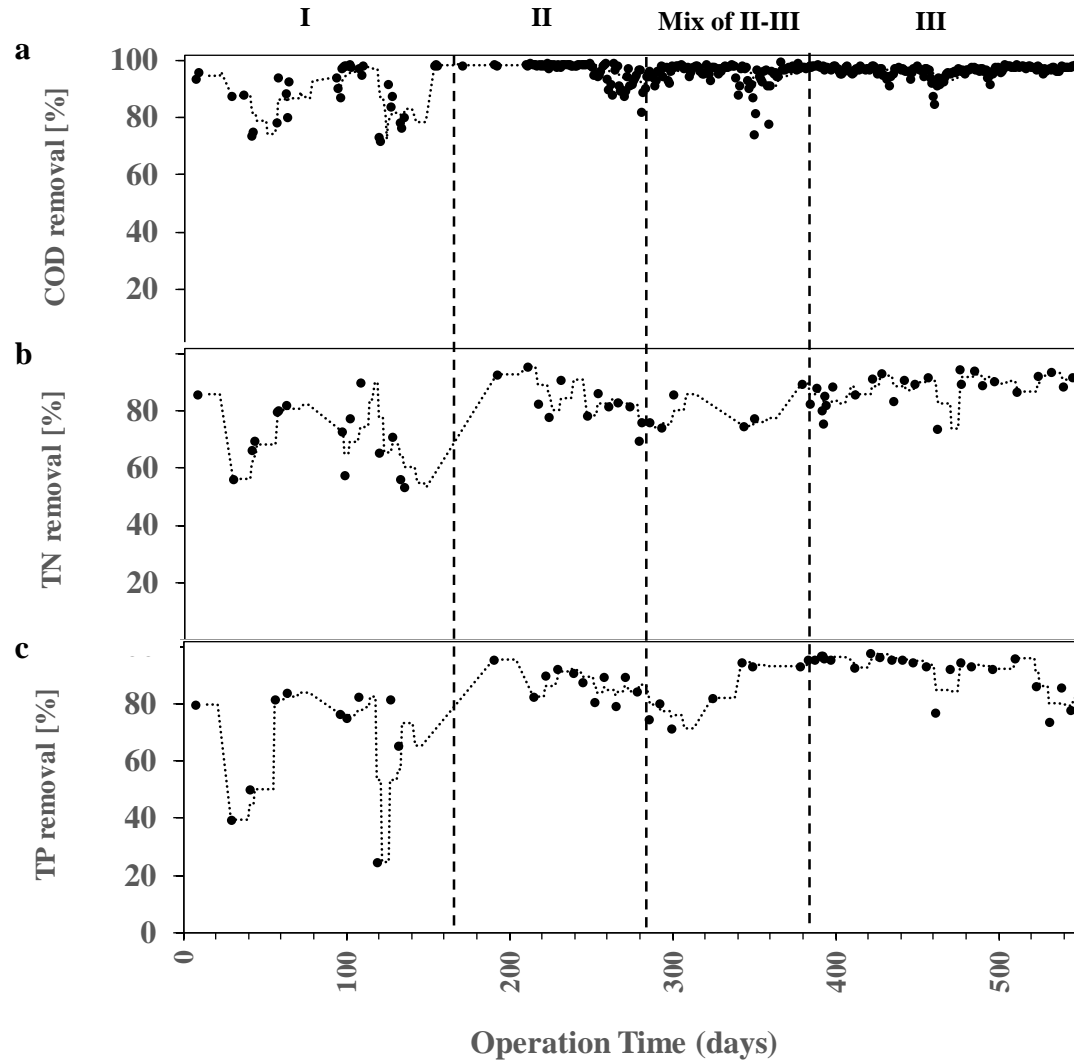
II



III



Performances of the plant



Comparison of operating parameters

Parameter	Unit	Conventional	Densification
		I	III
Sludge retention time	d	24 - 37	29 -54
Total suspended solids	kg m ⁻³	2.7 - 3.6	3.2 - 3.8
Sludge loading total	kg COD (kg TSS d) ⁻¹	0.150	0.102
Sludge loading biological	kg COD (kg TSS d) ⁻¹	0.232	0.233
Biological sludge production	kg DW (kg COD _{in WWTP}) ⁻¹	0.237	0.238
Volumetric load	m ³ (m ³ _{SBRs} d) ⁻¹	0.295	0.248
Specific energy demand for aeration	kwh (kg COD _{in bio}) ⁻¹	1.06	0.74

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Key messages

- **Filamentous bulking caused by VFA-consuming bacteria can be solved with a granulation strategy**
- **The metabolic selection is sufficient to form granules**
- **Aeration and settling time can be maintained at conventional values**
- **Granulation strategy reduces the energy demand**

Acknowledgements

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Denis Lamouline

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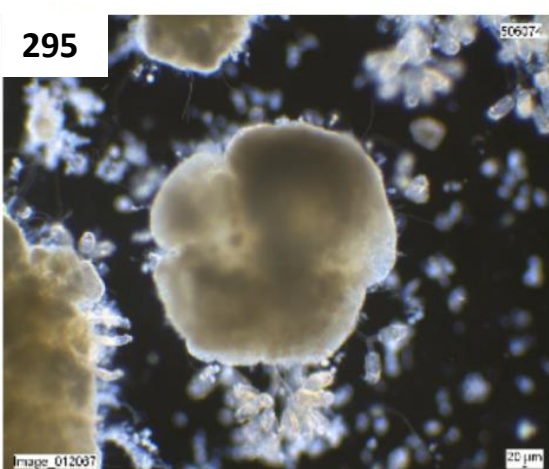
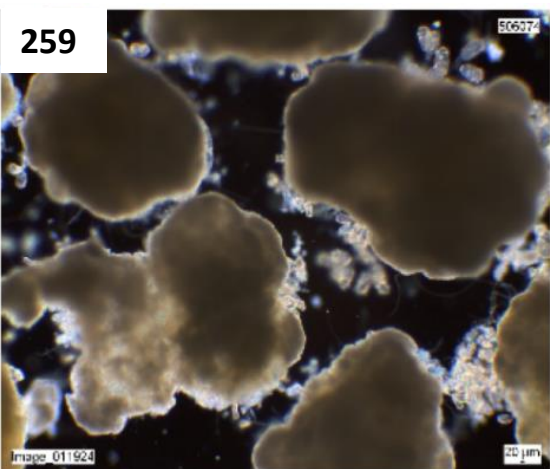
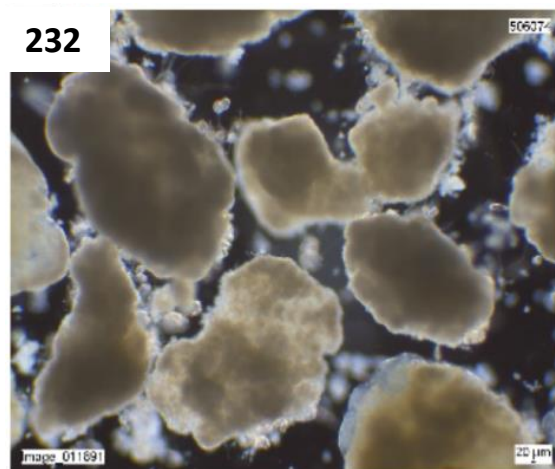
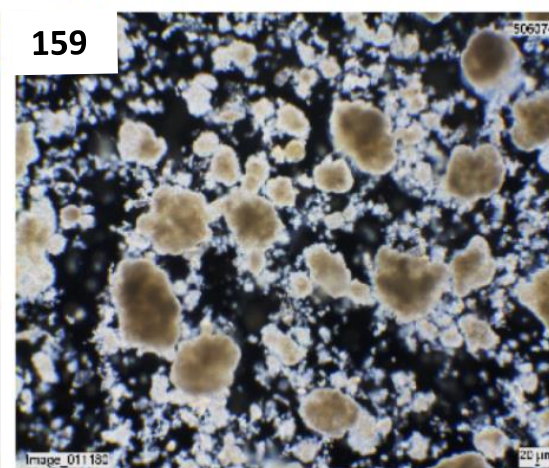
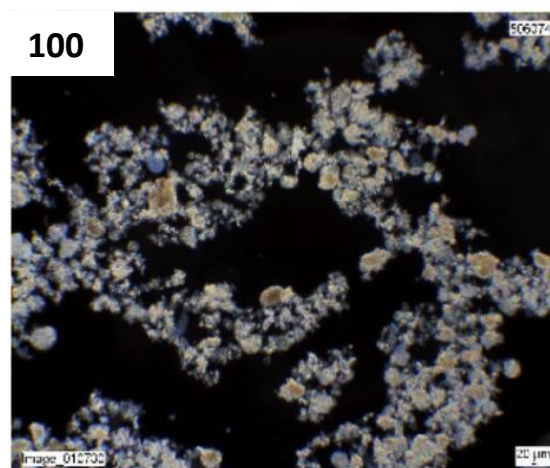
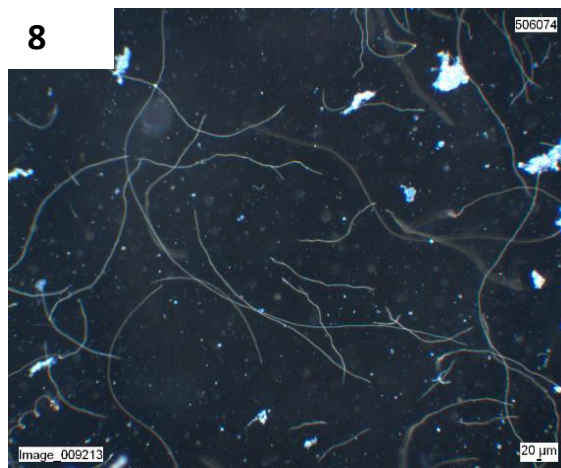
Olivier Henriet

January 25, 2018

Lab-scale assessment of the granulation strategy

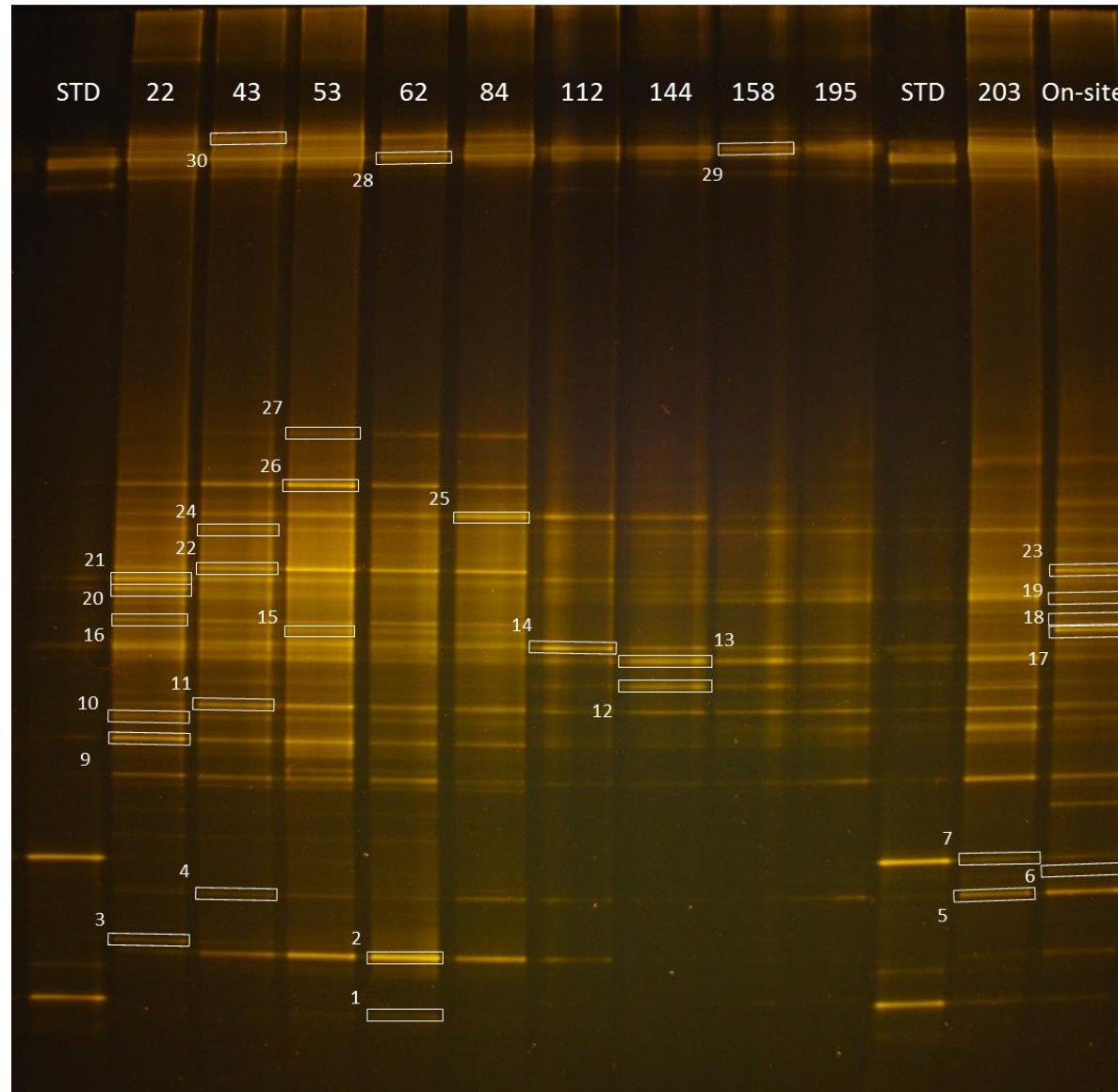
Periods		I	II	III	IV
Days		1-7	8-100	101 -160	161- 300
		Initiation	Storage metabolisms	Intensification	Maturation
<i>General characteristics</i>					
Volume exchange ratio	%	17	17 - 36	36	36
Dissolved oxygen	mg L ⁻¹	3.0	>8.6	>8.6	3.0
<i>Cycle</i>					
Aerobic feed	min	80	0	0	0
Anaerobic feed	min	0	90	80	80
Aeration	min	365	382 - 393	270 - 150	147 - 152
Settling	min	30	1.5 - 5.0	5.0	3.5 - 8.0
Purge	min	5	5	5	5

Lab-scale assessment of the granulation strategy



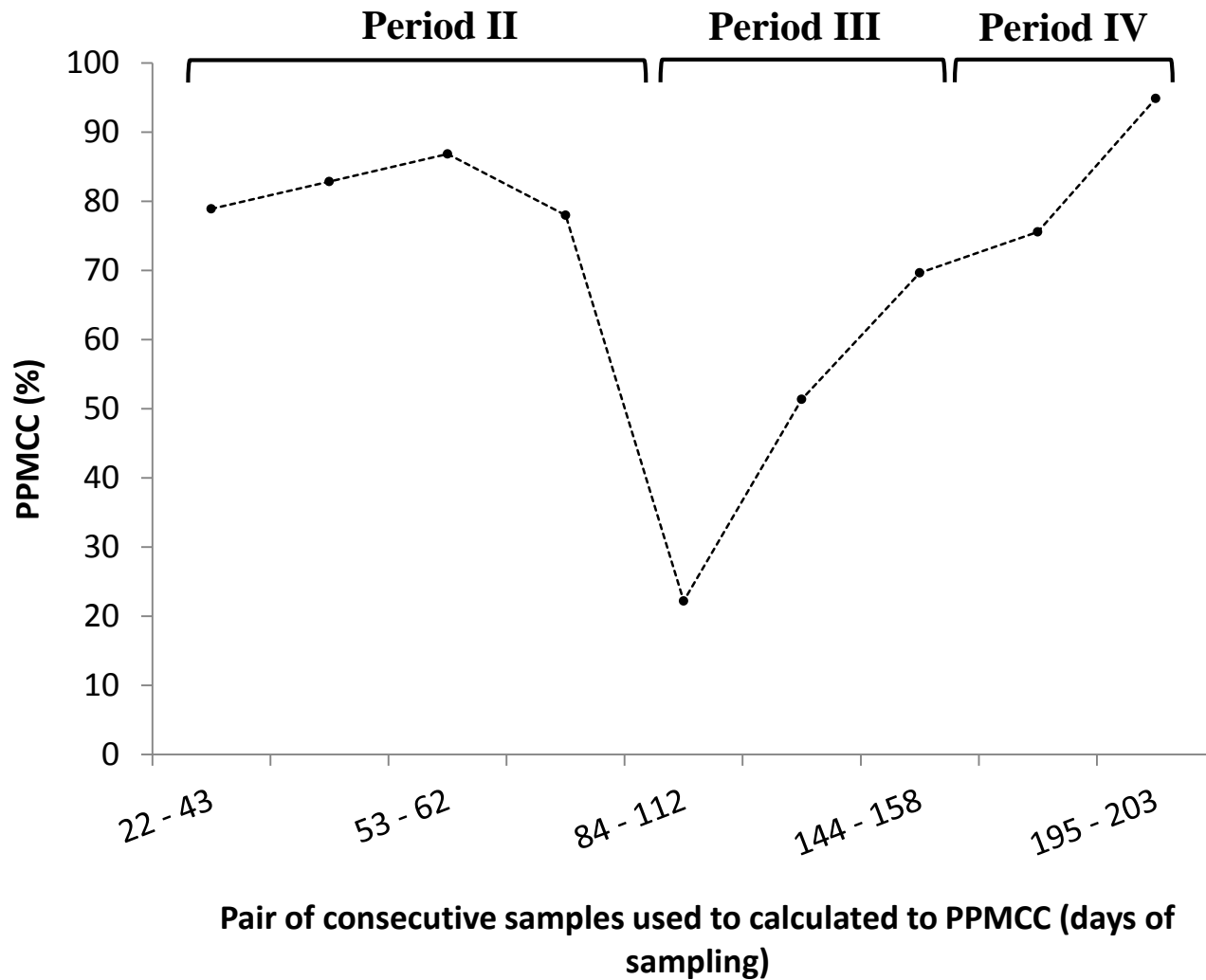
2 mm

Important switch of the microbial diversity



# OTU	Highest taxon. assignment
1 > 2	<i>Candidatus Competibacter</i> sp.
3	<i>Roseiflexus</i> sp.
4 > 7	<i>Candidatus Competibacter</i> sp.
8	<i>Bacteroidales</i> [order]
9	<i>Chiayiivirga flava</i>
10	<i>Caldilineaceae</i> [family]
11	<i>Gemmatimonas</i> sp.
12 > 13	<i>Thauera</i> sp.
14	<i>Lysobacter brunescens</i>
15	<i>Amaricoccus</i> sp.
16, 18	<i>Proteobacteria</i> [phylum]
17	<i>Byssovorax cruenta</i>
19	<i>Planctomycetia</i> [class]
20	<i>Polyangiaceae</i> [family]
21	<i>Xanthomonadaceae</i> [family]
22 > 23	<i>Zoogloea caeni</i>
24	<i>Propionivibrio</i> sp.
25	<i>Rhodocyclaceae</i> [family]
26	<i>Micrococcineae</i> [suborder]
27	<i>Acidobacteria</i> [class]
28, 30	<i>Saprospiraceae</i> [family]
29	<i>Candidatus Accumulibacter</i> sp.

Important switch of the microbial diversity



Important switch of the microbial diversity

# OTU	Highest taxonomic assignment	Period II					Period III			Period IV	
		22	43	53	62	84	112	144	158	195	203
30	<i>Saprospiraceae</i> [family]	█									
29	<i>Ca. Accumulibacter</i> sp.						█				
28	<i>Saprospiraceae</i> [family]	█									
23	<i>Zoogloea caeni</i>	█									
21	<i>Xanthomonadaceae</i> [family]	█									
20	<i>Polyangiaceae</i> [family]										
16	<i>Proteobacteria</i> [phylum]	█									
15	<i>Amaricoccus</i> sp.		█								
14	<i>Lysobacter brunescens</i>						█				
12	<i>Thauera</i> sp.		█				█				
10	<i>Caldilineaceae</i> [family]	█									
9	<i>Chiayiivirga flava</i>	█									
7	<i>Ca. Competibacter</i> sp.									█	
5	<i>Ca. Competibacter</i> sp.	█								█	█