



Fig. S1. QQ activity of initial beads Error bar: standard deviation ($n = 2$).

Table S1. Chemical composition of the synthetic wastewater for the operation of MBRs used in this study.

Chemicals	mg/l
Glucose (Samyang Genex, Seoul, Korea)	400
Yeast extract (BD Life Sciences)	14
Bactopectone (Laboratoris Conda, Madrid, Spain)	115
(NH ₄) ₂ SO ₄ (Daejung Chemical and Materials, Siheung, Korea)	104.75
KH ₂ PO ₄ (Duksan Pure Chemical)	21.75
MgSO ₄ ·7H ₂ O (Junsei chemical, Tokyo, Japan)	32
FeCl ₃ ·3H ₂ O (Junsei chemical, Tokyo, Japan)	0.125
CaCl ₂ ·2H ₂ O (Daejung Chemical and Materials, Siheung, Korea)	3.25
MnSO ₄ ·5H ₂ O (Junsei chemical, Tokyo, Japan)	2.875
NaHCO ₃ (Daejung Chemical and Materials, Siheung, Korea)	255.5

Table S2. The hydrodynamic resistance of the membrane (R_m) of each run.

Run	MBR	$R_m (\times 10^{11})$	
		Minimum	Maximum
1	Conventional-MBR	7.08	7.69
	QQ-MBR	7.08	8.09
2	Conventional-MBR	6.88	7.89
	QQ-MBR	6.67	7.89
3	Vacant-MBR	8.29	9.10
	QQ-MBR	7.69	8.67
4	Vacant-MBR	9.71	10.52
	QQ-MBR	9.51	10.11

Table S3. Relative composition (%) of dominant bacteria in biofilm.

OTU No.	Classification	Run1						Classification	Run2					
		Conventional-MBR			QQ-MBR				Conventional-MBR			QQ-MBR		
		TMP (kPa)							Time (d)					
		15	28	47	15	25	52		3	6	10	3	6	10
1	<i>Thiothrix</i>	30.6	19.6	32.4	23.1	21.9	24.8	<i>Thiothrix</i>	29.9	23.1	21.3	26.2	18.4	14.6
2	<i>Rhodobacter</i>	2.4	3.6	3.5	2.8	2.0	2.0	<i>Chloroflexi*</i>	4.0	4.3	5.2	2.7	2.3	2.7
3	<i>unclassified*</i>	7.7	7.2	3.9	5.0	2.1	0.7	<i>Bacteroidetes*</i>	6.3	6.8	4.6	1.8	2.9	2.0
4	<i>unclassified*</i>	2.7	4.7	4.9	3.8	4.2	4.7	<i>Haliscomenobacter</i>	2.5	4.1	3.3	3.4	4.8	4.0
5	<i>Dokdonella</i>	1.5	4.2	2.9	4.4	3.7	4.0	<i>Rhodobacter</i>	1.6	1.9	2.7	1.7	2.2	2.6
6	<i>Chloroflexi*</i>	0.7	1.1	2.6	1.2	1.2	2.5	<i>Cytophagaceae*</i>	1.6	2.4	2.8	1.2	2.3	4.8
7	<i>Sphingobacteriales*</i>	0.9	2.2	1.8	2.9	2.2	3.0	<i>unclassified*</i>	2.5	3.7	2.7	2.8	2.6	1.1
8	<i>Gp4*</i>	1.8	2.3	1.6	1.9	1.8	1.2	<i>Lactococcus</i>	0.9	1.0	2.3	3.3	2.1	5.9
9	<i>Cytophagaceae*</i>	1.2	1.3	1.2	1.7	1.6	0.7	<i>Chlamydiales*</i>	3.6	3.5	0.7	0.8	0.4	0.2
10	<i>Nannocystineae*</i>	0.4	2.2	2.9	1.3	2.8	3.4	<i>Chloroflexi*</i>	1.5	1.4	1.6	1.4	1.1	1.3
OTU No.	Classification	Run3						Classification	Run4					
		Vacant-MBR			QQ-MBR				Vacant-MBR			QQ-MBR		
		TMP (kPa)							Time (d)					
		16	30	50	14	25	46		5	11	13	5	11	13
1	<i>Thiothrix</i>	8.4	16.7	11.3	5.4	11.7	3.6	<i>Thiothrix</i>	24.9	22.1	4.8	15.9	15.8	9.3
2	<i>Tolumonas</i>	23.6	1.7	0.5	0.4	2.7	0.0	<i>Sphingomonadaceae*</i>	5.5	23.2	30.8	4.2	7.8	7.6
3	<i>Chloroflexi*</i>	1.9	2.8	3.1	1.8	1.5	1.2	<i>Nitrospira</i>	2.9	2.4	0.7	2.6	2.1	2.7
4	<i>Haliscomenobacter</i>	0.0	1.6	3.2	4.4	3.0	3.8	<i>Rhodobacter</i>	2.6	1.7	0.7	1.8	2.0	2.1
5	<i>Cytophagaceae*</i>	3.3	2.8	1.4	4.2	1.6	1.3	<i>Chloroflexi*</i>	2.3	1.9	1.1	2.3	2.1	2.2
6	<i>Rhodobacter</i>	0.5	1.4	1.7	2.1	2.0	2.7	<i>Chloroflexi*</i>	3.8	3.2	0.3	1.3	0.7	0.7
7	<i>Pseudomonas</i>	2.4	1.8	1.4	4.7	3.5	3.3	<i>Rhodocyclaceae*</i>	1.4	1.0	1.4	3.2	2.1	1.3
8	<i>Dokdonella</i>	0.4	1.7	3.4	3.3	1.9	1.9	<i>Geminicoccus</i>	1.9	2.0	0.9	1.7	1.6	1.4
9	<i>Gp4*</i>	0.5	1.3	2.1	4.0	2.1	1.4	<i>Ferruginibacter</i>	1.9	1.0	0.8	1.3	1.4	2.3
10	<i>Nitrospira</i>	0.4	0.4	1.3	1.6	2.4	4.9	<i>Parachlamydiaceae*</i>	1.1	0.1	7.0	3.0	1.4	0.2

OTU was classified at the genus level, and the asterisk indicates that the OTU was assigned at the taxonomic classification level.