A mechanistic model for operation and control of purple phototrophic raceway reactors: microbial selection dynamics and wastewater treatment performance

Abbas Alloul[a,c,1], Ali Moradvandi[b,e,1,*], Daniel Puyol[d], Raúl Molina[d], Giorgio Gardella[b], Siegfried E. Vlaeminck[a], Bart De Schutter[e], Edo Abraham[b], Ralph E. F. Lindeboom[b], David G. Weissbrodt[c]

[a]*Research Group of Sustainable Energy, Air and Water Technology, Department of Bioscience Engineering, University of Antwerp, Groenenborgerlaan 17, 2020, Antwerpen, Belgium*
[b]*Department of Water Management,Delft University of Technology, Mekelweg 5, 2628 CD, Delft, The Netherlands*
[c]*Department of Biotechnology, Delft University of Technolog, Maasweg 9, Delft, 2629 HZ, The Netherlands*
[d]*Group of Chemical and Environmental Engineering, University Rey Juan Carlos, 28933, Madrid, Spain*
[e]*Delft Center for Systems and Control, Delft University of Technology, Mekelweg 2, 2628 CD, Delft, The Netherlands*

This document consists of the supplementary materials of PPB model. The parameters that are needed to run the simulation can be found in the table below. The parameters that are not calibrated have been taken from the references below.

*Corresponding author: A. Moradvandi: a.moradvandi@tudelft.nl
[1]Abbas Alloul and Ali Moradvandi contributed equally as first co-author.

Symbol	Definition	Value	Unit
Kinetic parameters			
$\mu_{m,SS,PB,ph}$	Maximal specific phototrophic growth rate of PPB on soluble organics	0.0525	h^{-1}
$\mu_{m,VFA,PB,ph}$	Maximal specific phototrophic growth rate of PPB on volatile fatty acids	0.0783	h^{-1}
$\mu_{m,SS,PB,ch}$	Maximal specific aerobic chemotrophic growth rate of PPB on soluble organic	0.0500	h^{-1}
$\mu_{m,VFA,PB,ch}$	Maximal specific aerobic chemoheterotrophic growth rate of PPB on volatile fatty acids	0.0525	h^{-1}
$\mu_{m,SS,PB,an}$	Maximal specific anerobic chemoheterotrophic growth rate of PPB on soluble organic	0.0124	h^{-1}
$b_{m,PB,dec}$	Specific decay rate of PPB	0.0113	h^{-1}
$\mu_{m,SS,AHB}$	Maximal specific growth rate of AHB on soluble organics	0.0758	h^{-1}
$\mu_{m,VFA,AHB}$	Maximal specific growth rate of AHB on volatile fatty acids	0.0758	h^{-1}
$b_{m,AHB,dec}$	Specific decay rate of AHB	0.0156	h^{-1}
$\mu_{m,SS,AN}$	Maximal specific growth rate of AN on soluble organics	0.0238	h^{-1}
$b_{m,AN,dec}$	Specific decay rate of AN	0.00083	h^{-1}
μ_{hyd}	Hydrolysis rate of suspended solids	0.0035	h^{-1}
$K_{S,E}$	Light half-saturation constant of PPB	3	$W\,m^{-2}$
$K_{I,E}$	Light inhibitory constant for chemotrophic growth of PPB	100	$W\,m^{-2}$
$K_{I,O2,PB}$	Oxygen inhibitory constant for phototrophic growth of PPB	0.7	$mgCODL^{-1}$
$K_{S,O2,PB}$	Oxygen half-saturation constant for chemotrophic growth of PPB	0.05	$mgCODL^{-1}$
$K_{I,O2,AHB}$	Oxygen half-saturation constant for AHB	0.05	$mgCODL^{-1}$
$K_{I,O2,AN}$	Oxygen inhibitory constant for AN	0.05	$mgCODL^{-1}$
$K_{S,SS,ph}$	Soluble organic half-saturation constant for phototrophic growth of PPB	5	$mgCODL^{-1}$
$K_{S,VFA,ph}$	Volatile fatty acid half-saturation constant for phototrophic growth of PPB	20	$mgCODL^{-1}$
$K_{S,SS,ch}$	Soluble organic half-saturation constant for chemotrophic growth of PPB	0.4	$mgCODL^{-1}$
$K_{S,VFA,ch}$	Volatile fatty acid half-saturation constant for chemotrophic growth of PPB	0.4	$mgCODL^{-1}$
$K_{S,SS,an}$	Soluble organic half-saturation constant for anaerobic chemotrophic growth of PPB	5	$mgCODL^{-1}$
$K_{S,SS,AHB}$	Soluble organic half-saturation constant for AHB	5	$mgCODL^{-1}$
$K_{S,VFA,AHB}$	Volatile fatty acid half-saturation constant for AHB	5	$mgCODL^{-1}$
$K_{S,SS,AN}$	Soluble organic half-saturation constant for AN	5	$mgCODL^{-1}$
$K_{S,IN}$	Inorganic nitrogen half-saturation constant	0.005	$mgCODL^{-1}$
$K_{S,IP}$	Inorganic phosphorus half-saturation constant	0.001	$mgCODL^{-1}$
M_S	Metabolic switch	0.28	
Stoichiometric parameters			
$Y_{PB,ph}$	Biomass yield for phototrophic growth of PPB	1.00	$mgCODmgCOD^{-1}$
$Y_{PB,ch}$	Biomass yield for aerobic chemotrophic growth of PPB	0.52	$mgCODmgCOD^{-1}$
$Y_{PB,an}$	Biomass yield for anaerobic chemotrophic growth of PPB	0.197	$mgCODmgCOD^{-1}$
Y_{AHB}	Biomass yield for AHB	0.67	$mgCODmgCOD^{-1}$
Y_{AN}	Biomass yield for AN	0.197	$mgCODmgCOD^{-1}$
$f_{IC,ph,SS}$	Stoichiometry of inorganic carbon produced for phototrophic growth of PPB on soluble organics	3.897702e-3	$mgCODmgCOD^{-1}$

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Symbol	Definition	Value	Unit
$f_{IC,ph,VFA}$	Stoichiometry of inorganic carbon produced for phototrophic growth of PPB on volatile fatty acids	3.897702e-3	$\mathrm{mgCODmgCOD^{-1}}$
$f_{IC,ch,SS}$	Stoichiometry of inorganic carbon produced for aerobic chemotrophic growth of PPB on soluble organics	0.01400	$\mathrm{mgCODmgCOD^{-1}}$
$f_{IC,ch,VFA}$	Stoichiometry of inorganic carbon produced for aerobic chemotrophic growth of PPB on volatile fatty acids	0.023728	$\mathrm{mgCODmgCOD^{-1}}$
$f_{IC,an,SS}$	Stoichiometry of inorganic carbon produced for anaerobic chemotrophic growth of PPB on soluble organics	-0.02702	$\mathrm{mgCODmgCOD^{-1}}$
$f_{IC,AHB,SS}$	Stoichiometry of inorganic carbon produced for growth of AHB on soluble organics	0.01400	$\mathrm{mgCODmgCOD^{-1}}$
$f_{IC,AHB,VFA}$	Stoichiometry of inorganic carbon produced for growth of AHB on volatile fatty acids	0.023728	$\mathrm{mgCODmgCOD^{-1}}$
$f_{IC,AN,SS}$	Stoichiometry of inorganic carbon produced for growth of AN on soluble organics	-0.02702	$\mathrm{mgCODmgCOD^{-1}}$
$f_{IC,dec}$	Inorganic carbon produced from bacterial biomass decay	-1.984127e-04	$\mathrm{mmolHCO_3 - CmgCOD^{-1}}$
$f_{IN,dec}$	Inorganic nitrogen produced from bacterial biomass decay	0.058	$\mathrm{mgNH_3 - NmgCOD^{-1}}$
$f_{IP,dec}$	Inorganic phosphorus produced from bacterial biomass decay	0.01	$\mathrm{mgPO_4 - PmgCOD^{-1}}$
$f_{SIC,XS}$	Suspended solids produced from hydrolysis	1.303971e-06	$\mathrm{mmolHCO_3 - CmgCOD^{-1}}$
$f_{SS,XS}$	Soluble organics produced from hydrolysis	1.638241-01	$\mathrm{mgCODmgCOD^{-1}}$
$f_{SH2,XS}$	Hydrogen produced from hydrolysis	8.442468e-02	$\mathrm{mmolHCO_3 - CmgCOD^{-1}}$
$f_{SIN,XS}$	Inorganic nitrogen produced from hydrolysis	1.162246-02	$\mathrm{mgNH_3 - NmgCOD^{-1}}$
$f_{SIP,XS}$	Inorganic phosphorus produced from hydrolysis	2.075440e-03	$\mathrm{mgPO_4 - PmgCOD^{-1}}$
$f_{SI,XS}$	Inert soluble organics produced from hydrolysis	1.518208e-01	$\mathrm{mgCODmgCOD^{-1}}$
$f_{XI,XS}$	Inert suspended solids produced from hydrolysis	4.330911e-01	$\mathrm{mgCODmgCOD^{-1}}$
$f_{VFA,AN,SS}$	Fraction of VFA produced during acidogenic fermentation	0.7728	$\mathrm{mgCODmgCOD^{-1}}$
$f_{H2,AN}$	Fraction of hydrogen produced during acidogenic fermentation	0.0304	$\mathrm{mgCODmgCOD^{-1}}$
$Y_{N,PB}$	Nitrogen content of PPB	-0.0860	$\mathrm{mgNmgCOD^{-1}}$
$Y_{N,AHB}$	Nitrogen content of AHB	-0.0860	$\mathrm{mgNmgCOD^{-1}}$
$Y_{N,AN}$	Nitrogen content of AN	-0.0860	$\mathrm{mgNmgCOD^{-1}}$
$Y_{P,PB}$	Phosphorus content of PPB	-0.0150	$\mathrm{mgPmgCOD^{-1}}$
$Y_{P,AHB}$	Phosphorus content of AHB	-0.0150	$\mathrm{mgPmgCOD^{-1}}$
$Y_{P,AN}$	Phosphorus content of AN	-0.0150	$\mathrm{mgPmgCOD^{-1}}$
Physico-chemical parameters			
ϵ	Light extinction coefficient	0.07	
σ	Light absorbance and scattering factor	1.15	
S_{E0}	Light intensity	54	$\mathrm{W\,m^{-2}}$
$P_{ka_{CO_2}}$	Acid-base equilibrium coefficient for inorganic carbon	6.37	
$P_{ka_{NH_4}}$	Acid-base equilibrium coefficient for inorganic nitrogen	9.25	
Kla_{O2}	Oxygen gas-liquid transfer coefficient	1	$\mathrm{h^{-1}}$
Kla_{CO2}	Carbon dioxide gas-liquid transfer coefficient	0.0127	$\mathrm{h^{-1}}$
Kla_{NH3}	Ammonia gas-liquid transfer coefficient	0.533186	$\mathrm{h^{-1}}$
Kla_{H2}	Hydrogen gas-liquid transfer coefficient	1.6	$\mathrm{h^{-1}}$
O_2^{sat}	Saturated oxygen	7.85	$\mathrm{mgO_2L^{-1}}$
CO_2^{sat}	Saturated carbon dioxide	0.0127	$\mathrm{mmolHCO_3^-\,L^{-1}}$
NH_3^{sat}	Saturated ammonia	0.533186	$\mathrm{mgNL^{-1}}$
H_2^{sat}	Saturated hydrogen	1.6	$\mathrm{mgH_2L^{-1}}$

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Symbol	**Definition**	**Value**	**Unit**
$f_{O2,PB}$	Oxygen uptake chemoheterotrophy of PPB	$\frac{-(1-Y_{PB,ch})}{Y_{PB,ch}}$	$mgO2mgCOD^{-1}$
$f_{O2,AHB}$	Oxygen uptake chemoheterotrophy of AHB	$\frac{-(1-Y_{AHB})}{Y_{AHB}}$	$mgO2mgCOD^{-1}$
Reactor geometry			
V	Volume	100	L
A	Area	0.5	m
$f_{H/S}$	Fraction of removed particles	$\frac{HRT}{SRT}$	

References

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