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Biodegradability of wastewater and activated sludge organics in anaerobic digestion

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ABSTRACT

The investigation provides experimental evidence that the unbiodegradable particulate organics fractions of primary sludge and waste activated sludge calculated from activated sludge models remain essentially unbiodegradable in anaerobic digestion. This was tested by feeding the waste activated sludge (WAS) from three different laboratory activated sludge (AS) systems to three separate anaerobic digesters (AD). Two of the AS systems were Modified Ludzack – Ettinger (MLE) nitrification-denitrification (ND) systems and the third was a membrane University of Cape Town (UCT) ND and enhanced biological P removal system. One of the MLE systems and the UCT system were fed the same real settled wastewater. The other MLE system was fed raw wastewater which was made by adding a measured constant flux (gCOD/d) of macerated primary sludge (PS) to the real settled wastewater. This PS was also fed to a fourth AD and a blend of PS and WAS from settled wastewater MLE system was fed to a fifth AD. The five ADs were each operated at five different sludge ages (10–60d). From the measured performance results of the AS systems, the unbiodegradable particulate organic (UPO) COD fractions of the raw and settled wastewaters, the PS and the WAS from the three AS systems were calculated with AS models. These AS model based UPO fractions of the PS and WAS were compared with the UPO fractions calculated from the performance results of the ADs fed these sludges. For the PS, the UPO fraction calculated from the AS and AD models matched closely, i.e. 0.30 and 0.31. Provided the UPO of heterotrophic (OHO, f_{E_OHO}) and phosphorus accumulating (PAO, f_{E_PAO}) biomass were accepted to be those associated with the death regeneration model of organism "decay", the UPO of the WAS calculated from the AS and AD models also matched well - if the steady state AS model $f_{E\_OHO} = 0.20$ and $f_{E\_PAO} = 0.25$ values were used, then the UPO fraction of the WAS calculated from the AS models deviated significantly from those calculated with the AD models. Therefore in plant wide wastewater treatment models the characterization of PS and WAS as defined by the AS models can be applied without modification in AD models. The observed rate limiting hydrolysis/acidogenesis rates of the sludges are listed.

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List of abbreviations

AD	Anaerobic digestion
ADM1	Anaerobic digestion models No 1
AS	Activated sludge
ASM1, 2, 2d	Activated sludge models No 1, 2 and 2d
BPO	Biodegradable particulate organics
BSM2	Benchmark simulation model No 2
BSO	Biodegradable soluble organics
COD	Chemical oxygen demand
d	Day
DSVI	Diluted sludge volume index
EBPR	Enhanced biological phosphorus removal
F	Filtered
F-BSO	Fermentable biodegradable soluble organics
FSA	Free and saline ammonia
g	gram
ISS	Inorganic suspended solids
l	Litre
m	Metre
MLE	Modified Ludzack-Ettinger system
N	Nitrogen
ND	Nitrification-denitrification
OHO	Ordinary heterotrophic organism
OUR	Oxygen utilization rate
P	Phosphorus
OP	Ortho-phosphate
PAO	Phosphorus accumulating organisms
PP	Polyphosphate
PS	Primary sludge
pH	Negative log of the hydrogen ion activity
SRT	Solids retention time (or sludge age)
TKN	Total Kjeldahl nitrogen
TP	Total phosphorus
TSS	Total suspended solids
UCT	University of Cape Town
UF	Unfiltered
UPO	Unbiodegradable particulate organics
USO	Unbiodegradable soluble organics
VFA	Volatile fatty acids
VSS	Volatile suspended solids
WAS	Waste activated sludge
WRC	Water Research Commission
WW	Wastewater
WWTP	Wastewater treatment plant

List of symbols[1]

b, /d	general parameter for endogenous respiration rate
E, –	Proportion of influent COD flux (gCOD/d) exiting system as sludge production (gCOD/d)
f_E, –	general parameter for unbiodegradable fraction of biomass
f_{COD_VSS}, gCOD/gVSS	COD content of organics (COD/VSS ratio, f_{cv})
f_{OHO_VSS}, gVSS/gVSS	OHO/VSS ratio of activated sludge ($=X_{OHO}/X_{VSS}$, f_{av})
f_{xE_OHO}, –	OHO unbiodegradable fraction associated with endogenous respiration in steady state ND AS model (=0.20, f_{EH})
f'_{xE_OHO}, –	OHO unbiodegradable fraction associated with death regeneration in dynamic ASM1 (=0.08, f'_{EH})
f_{xE_PAO}, –	PAO unbiodegradable fraction associated with endogenous respiration in steady state NDEBPR AS model (=0.25, f_{EG})
f'_{xE_PAO}, –	PAO unbiodegradable fraction when assigned the same value as OHOs associated with death regeneration (=0.08, f'_{EG})
f_{P_VSS}, gP/gVSS	Phosphorus content of particulate organics or biomass (f_p)
$f_{xU,CODInf}$, gCOD/gCOD	fraction of influent total COD that is unbiodegradable and particulate ($f_{S'up}$)
$f_{SU,CODInf}$, gCOD/gCOD	fraction of influent total COD that is unbiodegradable and soluble ($f_{S'us}$)
k_h, /d	Specific hydrolysis/acidogenesis rate of BPO in AD
k_H, gCOD/(l.d)	First order specific hydrolysis/acidogenesis rate of BPO in AD
k_m, gCOD/gCOD/d	Maximum BPO hydrolysis/acidogenesis rate in AD in Monod kinetics in AD
k_M, gCOD/gCOD/d	Maximum BPO hydrolysis/acidogenesis rate in AD in saturation kinetics in AD
K_s, gCOD/l	Half saturation concentration for BPO hydrolysis/acidogenesis in Monod kinetics in AD
K_S, gCOD/l	Half saturation concentration for BPO hydrolysis/acidogenesis in saturation kinetics in AD
r_{hyd}, gCOD/(l.d)	Volumetric BPO hydrolysis rate in AD
$X_{B,Eff}$, mgCOD/l	effluent biodegradable particulate COD concentration (S_{bpe})
$X_{B,Inf}$, mgCOD/l	influent biodegradable particulate COD concentration (S_{bpi})
$S_{B,Inf}$, mgCOD/l	influent biodegradable soluble COD concentration (S_{bsi})
$X_{U,Eff}$, mgCOD/l	effluent unbiodegradable particulate COD concentration (S_{upe})

1. Introduction

In plant wide modelling, a question that arises is "do organics that are unbiodegradable in the activated sludge (AS) system, namely, the unbiodegradable particulate organics (UPO, $X_{U,Inf}$)

[1] As recommended by Corominas et al. (2010) with the UCT equivalent given in brackets for easy cross reference to the papers on the AS and AD steady state models in the old units.