FINDING OF COEFFICIENTS AND OXIDIZABLE NITROGEN FROM PALM OIL MILL EFFLUENT (POME) FOR ACTIVATED SLUDGE MODELS (ASMs)

A. Damayanti*, Mohd Razman Salim, Zaini Ujang

*Institute Technology Sepuluh Nopember (ITS), Surabaya, Indonesia
**Institute of Environmental & Water Resource Management,
Universiti Teknologi Malaysia,
81310 Skudai, Johor, Malaysia

*Corresponding Author: aliadamayanti@yahoo.com

Abstract: Activated Sludge Models (ASMs) have been widely used as a basis for further model development in wastewater treatment processes. Values for parameters to be used are vital for the accuracy of the modeling approach. The objective of this study is to determine coefficients of the system, and oxidizable nitrogen of palm oil mill effluent (POME). A continuous stirred tank reactor (CSTR), with continuous flow for 20 hours, was used in this study. The DO profile for 11 days was monitored. The total, soluble, insoluble COD and soluble ammonia nitrogen were measured at the beginning and end of the experiment. Also, the coefficients and oxidizable nitrogen fractions are determined.

Keywords: *Activated Sludge Models (ASMs); COD fractionations; palm oil mill effluent; DO; coefficients*

1. 0   Introduction

Coefficients values to be used for activated sludge modeling of POME are important in order to develop a model that can serve as a basis for design and optimization of a POME treatment process. This is due to the fact that POME has not been thoroughly studied from an Activated Sludge Models (ASMs) perspective, and most of the parameter values that are considered default values are based on municipal sewage. The maximum allowable limit set by the Malaysian Department of Environment (DOE, 2008) for oil and grease level is 50 mg/l and for BOD parameter it is 20 mg/L. This makes it is a challenge to balance between environmental and financial considerations.

The introduction of ASMs by the IWA task group (Henze *et al.*, 1987; 2000) was of great importance, providing researchers and practitioners with a standardized set of basic models for biological wastewater treatment processes. The first model (ASM1) quickly established itself as the reference model and it is still widely used today, e.g. for the design and assessment of advanced control strategies (Henze *et al*., 2004, Devisscher

et al., 2006). This model is now widely accepted in the scientific community and the sanitary engineering profession (Abdul-Talib *et al.*, 2002; Ujang *et al*., 2004). ASM1 was developed primarily for municipal activated sludge to model and describe the removal of organic carbon compounds and ammonium-N, with facultative consumption of oxygen or nitrate as the electron acceptor. The subsequent ASM3 model (Gujer *et al*., 1999; Henze *et al.*, 2000; Ujang *et al.*, 2004) was also developed for biological N removal, with basically the same goals as ASM1. Denitrifying PAOs will, in ASM2, be modeled as denitrifying heterotrophs and small input of nitrate to the anaerobic tanks can be modeled without problems (Henze *et al*., 2000). It is intended to replace the latter as the new reference model, correcting for a number of shortcomings that have emerged from its applications, as thoroughly assessed by Gernaey *et al*. (2004). In order for a model to have utility in the design and operation of waste water treatment systems, it must be possible to evaluate parameter values whish are specific for POME and to estimate concentration of important component in the effluent.

The most important factor by which a model can be judged is through its ability to predict space-time dependent changes in the requirement for the electron acceptor. The purpose of this study was to find the COD fractionation, heterotrophic yield, K_{La}, and oxidizable nitrogen coefficient of activated sludge bacteria.

2.0 Material and Methods

2.1 Samples

A laboratory CSTR was filled with raw POME taken from Kulai Palm Oil Mill, Bukit Besar, Johor Bahru, Malaysia. Palm oil mill effluent samples varies with time depending on the discharge quality of the mill, climate and condition of the palm oil processing (Salmiati *et al.*, 2007). The liquid fraction of POME was stored at $4^{o}C$ and was used for this experiment. The samples were manually sieved in 5 mm mesh. It sieved because it replaced sedimentation processed.

2.2 The Reactor

The continuous stirred tank aerobic reactor an utilized in this study, is shown in Figure 1. The CSTR is equipped with an on-line DO (WTW Oxil97 oxygen meter) with a working volume of 10 L.
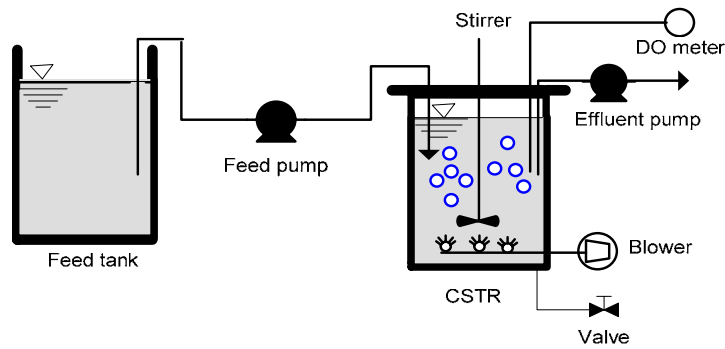
Figure 1 : Schematic layout of CSTR need in this study

2.3   Experimental

The CSTR system was operated without sludge recirculation, leading to a solids retention time equal to the hydraulic retention time. Each experiment was operated in three phases as shown in Table 1. The CSTR was equipped with a foam breaker working during the aerobic phases and a fine bubble diffusers fed with a blower. For the mixing, a magnetic stirrer is used to mix the POME in the CSTR.

Table 1. Experimental phases of CSTR

No	Phase	Time (hours)	Flowrate (mL/min)
1	Innoculation	9	-
2	Feed of substrate	14	2
3	Stop feed	219	-

Fisrt step is inoculation, 9 hours operated. Second step is feed of substrate, 14 hours operated. Feeding was stopped in the third phase and the process was operated for the next 9 days to observe the Oxygen Utilization Rate (mg/L.hr) or OUR (Droste, 1997), trendWhen the CSTR reached steady-state conditions and after the OUR dropped to a small value, approximately after the eleventh day, the characterization of the effluent was conducted.

2.4   Analytical Methods

DO was analyzed used DO (WTW Oxil97 oxygen meter). Chemical oxygen demand was analyzed using a spectrophotometer (HACH/DR 4000). All experimental procedures were conducted according to Standard Methods (APHA, 1992).

3. 0   Results and Discussion

3.1   *The POME characteristics*

The POME characteristics are shown in Table 2.

Table 2**.** Characteristics of POME

Parameter	Values	Range (DOE, 1999)
pH	5.6	3.4-5.2
Chemical Oxygen Demand	46,000	16,000-100,000
Total Solid	43,000	11,500-79,000
Suspended Solid	42,800	5,000-54,000
Non Volatile Suspended Solid	8,200	4,000-18,000
Volatile Suspended Solid	35,000	9,000-72,000
Ammonia-N	4	4-80
FFA (Free Fatty Acid)	180	-
CH_3COOH	2,500	-
PO_4^{3-}	86	-

*Note: all parameter's units in mg/L except pH

Palm oil mill effluent (POME) is a colloidal suspension, which contains 95–96% of water, 0.6–0.7% of oil and grease and 4–5% of total solids (Ma, 2000). It is thick brownish in color liquid and discharged at temperature between 80 and 90 ◦C. It is fairly acidic with pH ranging from 4.0 to 5.0.

3.2   *COD Fractionations and Heterotrophic Yield Coefficient*

The definition of COD fractionations and Y_H are shown in Table 3 that shows what to measure, to achieve the parameter. Parameter and characteristics which must be evaluated and information needed for ASM used for POME can be seen in Table 4. Para- meter values at Table 4 can be found from equation expressed at Table 3. Once Y_H is known, the concentration of readily biodegradable substrate in the influent, S_s, can be estimated by measuring the change in oxygen utilization rate (OUR) in a single completely mixed reactor operated at 10 days SRT (Sludge Retention Time) for POME. This is because any accumulated readily biodegradable substrate is rapidly used. The OUR will not drop to zero, however, because the accumulated slowly biodegradable substrate will continue to be used at the same rate an extended. Thus the immediate drop in OUR is associated only with the readily biodegradable material and can be used to find its concentration.

Table 3. Expressions needed to look for COD fractionations and Y_H

No	Equation
1.	$Total\ COD = S_S + X_S + X_I + S_I$
2.	$Cell\ COD = Total\ COD - COD_s$
3.	$S_S = \dfrac{\Delta OUR\ x\ V}{Q(1 - Y_H)}$

Table 4. Parameter and characteristics which must be evaluated and information needed for ASM used for POME

Symbol	Name	Prior information need	Values
Total COD	COD total of wastewater	S_S, S_i, X_S, X_i	45,000
S_S	Concentration of readily biodegradable substrate in waste water	Y_H	150
S_i	Inert soluble organic matter COD concentration in wastewater	-	26,000
X_S	Slowly biodegradable organic matter concentration in wastewater	X_i, S_s, S_i	2,700
X_i	Inert suspended organic matter concentration in wastewater	S_s, S_i	17,000
Y_H	yield for heterotrophic biomass	-	0.44
ΔCell COD	The differences from subtraction of total COD and COD_s at first and last study	-	11,400
COD_s	COD soluble	-	26,150

*Note: all parameter's units in mg/L except Y_H

From Figure 2 we find that Δ OUR is 6.9 mg/L.hr from Figure 2. The OUR is dropped from 34. 6 mg/L.hr to 27.7 mg/L.hr at the 9th day. S_S is obtained from Table 3 which is 150 mg/L. POME is different with domestic waste water (Warner *et al*, 1986 and Muller *et al*, 2003). This is demonstrated by the fact that Δ OUR from domestic waste water can be found after about 14th hour, while Δ OUR from POME can be found not until the tenth day.
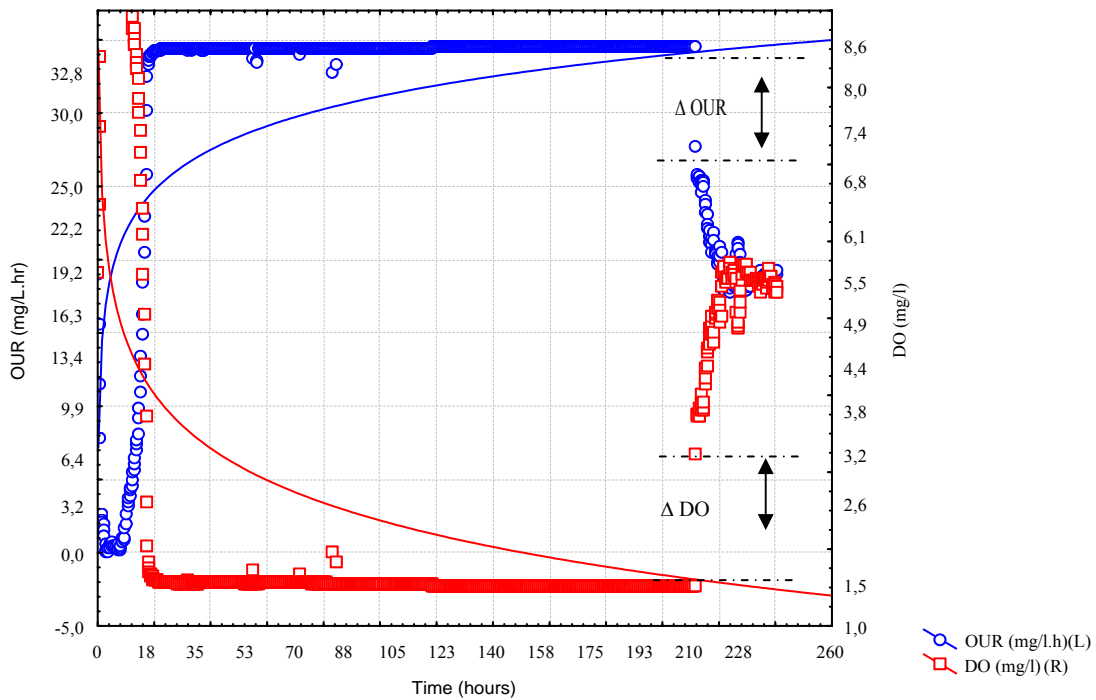
Figure 2: OUR for 10 days operation of completely mixed activated sludge reactor response as used to determined the concentration of readily biodegradable substrate

The OUR recording on Fig 3 shows that the microorganisms need some time (trend 2 , $r^2 = 0.97$; $y = -13.5 + 1.5x$, and trend 3, $r^2 = 0.98$; $y = -119 + 8.5x$, where x is time) from lag phase (trend 1),. The process works until about 15 hours, to adapt to the feed substrate. Then the OUR will increase rapidly to the maximum level and reaches a steady state at around t = 25 hours. When steady state had been reached at t = 25 hours (second phase: feed of substrate), then OUR (mg/L.h) = 35 mg/L.h. After the feed of substrate phase it is found the OUR increase to 34.4 mg/l from 0.4 mg/l. This trend is similar to domestic water phenomenon (Warner *et al.*, 1986 and Muller *et al.*, 2003).
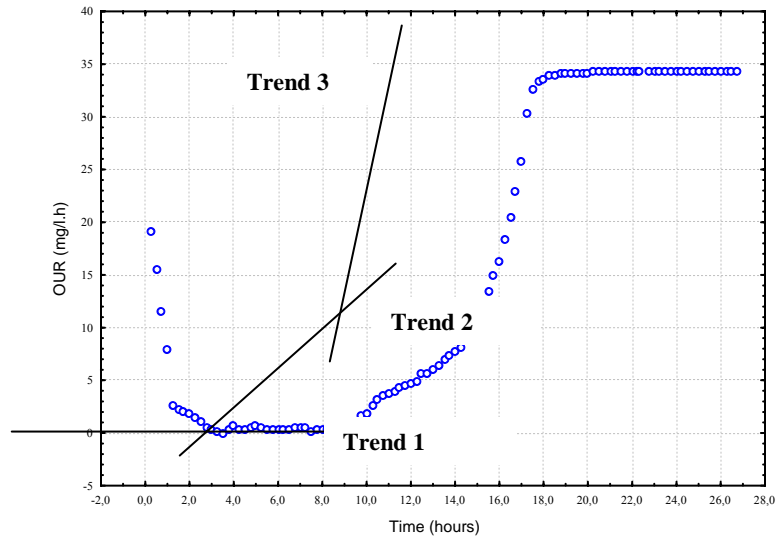
Figure 3: OUR for the first 30 hours operation of CSTR

Figure 4 demonstrates that there is a sudden decrease (trend 1), followed by a slower decrease of the OUR (trend 2, $r^2 = 0.94$, $y = 213 + 0.9x$), and lag phase (trend 3). Consequently, after the feed had been stopped the OUR change has a non-linear behaviour. This decreased is the same as with domestic water phenomenon (Warner *et al.*, 1986 and Muller *et al.*, 2003).
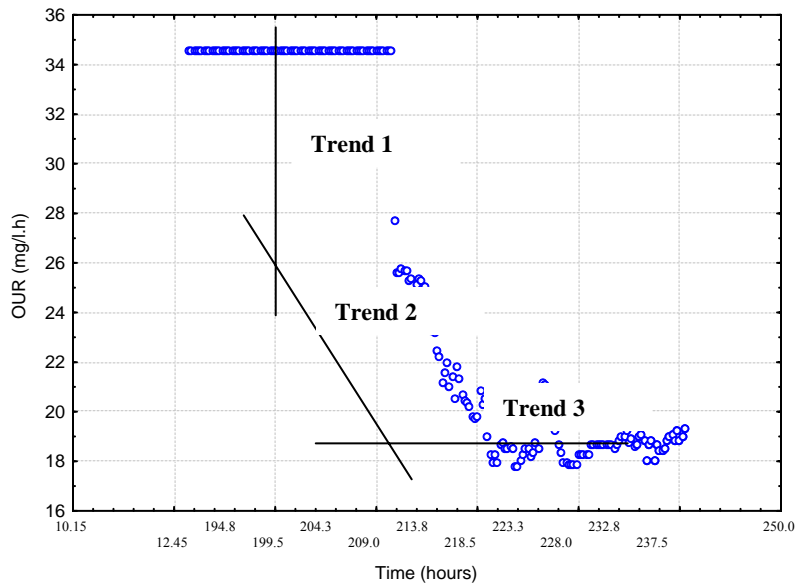

Figure 4: OUR for the last 40 hours operation of CSTR

3.3   Oxidizable nitrogen

Since the purpose of the model is to predict the performance of a single sludge system performing carbon oxidation, nitrification, and forming carbon oxidation, nitrification, and denitrification, it is important that the nitrogen is accounted for. As stated above, the concentration of ammonia nitrogen in the feed may be determined by appropriate of a filtered sample (Henze *et al*, 2000). Subtraction of the inert organic from that value approximates the readily biodegradable COD in the feed, then the concentration of readily biodegradable organic nitrogen in the feed is described by Equation 1.

$$\frac{S_{NHD}}{X_{NHD} + S_{NHD}} = \frac{S_S}{X_S + S_S} \tag{1}$$

Where:
S_{NHD} = Soluble biodegradable ammonia nitrogen concentration in waste water
X_{NHD} = Slowly biodegradable organic ammonia nitrogen concentration in wastewater

When S_S and X_S is found, S_{NHD} on POME had be examined, and is found to be 1.3 mg/l, from Equation 1, X_{NHD} is found to be 3.9 mg/L.

4. 0   Conclusions

In this study, key parameter of activated sludge models were developed and calibrated for the simulation of the modified continuous stirred tank reactor of raw POME. The results obtained the yield coefficient Y_H, of raw POME as 0.44. COD fractionation consisted of COD Total 45,000 mg/L, S_S 150 mg/L, X_S 25,000 mg/L, S_i 16,600 mg/L, and X_i 2700 mg/L. Oxidizable nitrogen was found as follows: S_{NHD} 1.3 mg/L and X_{NHD} 3.9 mg/L.

Acknowledgments

References:

Abdul-Talib S., Ujang Z., Vollertsen J. and Hvitved-Jacobsen, T. (2002). Determination of half saturation constants wastewater treatment. *Water Science Technology* **46**(9), 185-192.

Department of Environment (DOE). (2008). Industrial Processes and The Environment Crude Palm Oil Industry. Handbook No. 3. Ministry of Sciences, Technology and the Environment, Kuala Lumpur, Malaysia.

Devisscher, M., Ciacci, G., Fe´, L., Benedetti, L., Bixio, D., Thoeye, C., De Gueldre, G., Marsili-Libelli, S., Vanrolleghem, P.A., (2006). Estimating costs and benefits of advanced control for wastewater treatment plants the MAGIC methodology. *Water Science and Technology*. **53**(4-5), 215-223.

Droste, R.L., 1997. *Theory and Practice of Water and Wastewater Treatment.* John Wiley and Sons, Inc. 355-360.

Gernaey, K.V., van Loosdrecht, M.C.M., Henze, M., Lind, M., Jørgensen, S.B. (2004). Activated sludge wastewater treatment plant modelling and simulation: state of the art. *Environmental Modelling and Software*. **19**, 763-783.

Gujer, W., Henze, M., Mino, T., van Loosdrecht, M.C.M. (1999). Activated sludge model no. 3. *Water Science and Technology*. **39** (1), 183-193.

Hamdzah, M., Ujang, U., Ozaki, O. (2005). The effect of operational parameter for micropollutant removal using Low Pressure Reverse Osmosis Membrane (LPROM), The 2005 IWA -ASPIRE Regional Conference, 1350-1410.

Henze, M., Grady Jr., C.P.L., Gujer, W., Marais, G.V.R., and Matsuo, T. (1987). Activated Sludge Model No. 1. *IAWQ Scientific and Technical Report No. 1*, London, UK.

Henze, M., Gujer, W., Mino, T., Matsuo, T., Wentzel, M.C.M., Marais, G.V.R. (1995). Activated Sludge Model No. 2. *IWA Scientific and Technical Report No. 3*, London, UK.

Henze, M., Gujer W., Mino, T., van Loosdrecht, M.C.M. (2000). Activated Sludge Models ASM1, ASM2, ASM2d, and ASM3. *IWA Scientific and Technical Report*. IWA Publishing, London, UK.

Henze M. and Ujang Z. (2004). Environmental biotechnology problems in Ujang Z. Henze M. (eds) *Environmental Biotechnology*, Water and Environmental Management Series, IWA Publishing, London, 2004. pp. 19-26.

Ma, A.N. (2000). Environmental management for the palm oil industry, *Palm Oil Dev*. 30 1–10.

Muller, A., Wentzel, M.C., Loewenthal, R.E., and Ekama, G.A. (2003). Heterotroph an-oxic yield in anoxic aerobic activated sludge systems treating munical wastewater *Water Research*, **37**(10), 2435-2441

Munz, C. and P.V. Roberts. (1989). Gas and Liquid-Phase Mass Transfer Resistances of Organic Compounds during Mechanical Surface Aeration, *Water Research*, **23**(5) 589-601.

Nor Anuar, A., Ujang, Z., van Loosdrecht, M.C.M., and de Kreuk, M.K. (2007). Settling behaviour of aerobic granular sludge. *Water Science & Technology* . **56**(7), 55–63

Razak, A.R.A., Ujang, Z. and Ozaki, H. Removal of endocrine disrupting chemicals (EDCs) using low pressure reverse osmosis membrane (LPROM). *Water Science & Technology*. **56**(8),161–168.

Salmiati, Ujang, Z., Salim, M.R., Md Din, M.F., and Ahmad, M.A. (2007). Intracellular biopolymer productions using mixed microbial cultures from fermented POME. *Water Science & Technology*. **56**(8), 179–185.

Ujang Z., Henze M., Curtis T., Schertenleib R. and Beal L.L. (2004). Environmental Engineering Education for Developing Countries: Framework for the Future. *Water Science and Tech*nology. **49**(8), 1-10.

Ujang Z., Yong E.L., Ong P.T., Osuna R.R. and G.K. Anderson. (2004). The degradation of organic matter by microbial activity under anoxic conditions during transport in tropical sewer systems. In Ujang Z. Henze M. (eds) *Environmental Biotechnology*, Water and Environmental Management Series, IWA Publishing, London. pp. 51-60.

Warner, A.P.C., Ekama, G.A., and Marais, G.V.R. (1986). The activated sludge process—IV : Application of the general kinetic model to anoxic-aerobic digestion of waste activated sludge. *Water Research*, **20**(8), 943-958.