ACTIVATED SLUDGE PROCESS SIMULATOR ASP-SIM, PART-1: BOD AND TEMPERATURE MODEL.

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ABSTRACT

The most commonly used biological treatment of municipal and industrial wastewater is the Activated Sludge Process. The design of activated process is usually done manually; this is often difficult and susceptible to errors due to the large number of equations involved (which call for approximations and round off errors). Also, the determination of the effects of changes in design parameters are very difficult and time-consuming for manual computations. This paper therefore employs the Visual Basic 6.0 programming for design and simulation of completely mixed activated sludge (CMAS) process. Algorithm and flow chart based on kinetic model were used for developing the Visual Basic code, ASP-SIM. The code was tested using a design problem from standard text book. Results obtained proves that the Visual BASIC 6.0 program ASP-SIM is a useful tool for predicting the effect of temperature on design and operation of completely mixed activated plant design and operation.

KEY WORDS: Simulation, BOD, temperature, activated sludge process, and Visual Basic.

1. INTRODUCTION

The design of biological wastewater treatment plant is usually done by using equations based on mathematical models; in order to specify the plant dimensions, configurations, and process conditions. The design of activated sludge process for wastewater treatment using kinetic models involves solving complicated equations for a given condition (variable temperature). When the conditions change, the calculations have to be repeated. Activated sludge process plants are often installed and operated in locations with widely varying climatic conditions (Benefield & Randall, 1980; Tchobanoglous & Others, 2003; Agunwamba, 2007).

The effects of temperature change must therefore be considered in the design and operations of such plants. In most parts of the world with desert condition like North Africa and Northern part of Nigeria in particular, temperatures may range from as low as 12 ^{o}C during the months of December and January to as high as 40 ^{o}C during the months of March and April. This wide range in temperature may have serious consequence on the activated sludge process plant operation. Metabolic activities of

microorganism, oxygen transfer rate and the settling characteristics of biological solids are affected by temperature. To predict the effect of temperature on the activated sludge process plant design and operation requires the use of computer aided software. This paper focuses on the use of computer simulation to determine the effect of temperature on design and operation of completely mixed activated sludge process.

Extensive use of computer modeling and simulation in wastewater treatment processes began in the 1980s. Activated sludge process attracted a substantial interest with many simulation design models developed, among them is the activated sludge model No. 1 (ASM1) (Tchobanoglous and others, 2003). The ASM1 predicts the performance of biological processes in suspended growth systems including carbon oxidation, nitrification and denitrification; it has been revised several times and the revised versions named ASM2, and ASM3, respectively. The ASM2 was extended to include phosphorus removal reactions. Since the first release of the ASM1 in 1987, application of the original or modified versions of the model to a number of pilot and full-scale activated sludge systems with various process configurations has confirmed its

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ability to predict performance under steady-state and dynamic conditions.

Various software programs are available that apply model for different wastewater treatment processes. The most commonly used ones are SSSP, ASIM, EFOR, ENVIROPRO and GSP-X (Cimarosti and others, 2003). Computer simulation programs for wastewater discharge into rivers and streams also exist, a river mass transport model (RIMTRA) was developed and the computer code was written in FORTRAN IV (Nwaogazie, 1992). This model was revised in 1999 and 2002, respectively (Nwaogazie, 2004).

2.   MODEL DEVELOPMENT FOR COMPLETELY MIXED ACTIVATED SLUDGE (CMAS) PROCESS
Wastewater Characterization for CMAS Process Design

The first step in the design of CMAS process is the characterization of the wastewater. The kinetic model requires more detailed characterization than the semi-empirical model. For biological nutrient-removal processes, wastewater characterization is essential for predicting performance. Wastewater characterization is also an important element in the evaluation of existing facilities for optimizing performance and available treatment capacity. Wastewater characteristics of importance in the design of the activated-sludge process can be grouped into the following categories: carbonaceous substrates, nitrogenous compounds, phosphorous compounds, total and volatile suspended solids (TSS and VSS), and alkalinity. Table 1 shows some of the major parameters required for use in the kinetic model for CMAS.

Table 1: Typical domestic wastewater characterization parameters for CMAS design.

Parameter	Meaning
BOD	5-day Biochemical oxygen demand
sBOD	Soluble biochemical oxygen demand
COD	Chemical oxygen demand
sCOD	Soluble Chemical oxygen demand
rbCOD	Readily biodegradable Chemical oxygen demand
TKN	Total Kjeldahl nitrogen
NH_4-N	Ammonia nitrogen
TSS	Total suspended solids
VSS	Volatile suspended solids
TP	Total phosphorus
Alkalinity (as $CaCO_3$)	
bCOD/BOD ratio	

Activated Sludge Process Design Considerations

A number of process variables affect activated sludge process. Ignoring these variables may lead to poor design and operational problems in wastewater treatment plant. These process variables include: Hydraulic retention time, Solid retention time (SRT), Food to microorganism ratio (F/M ratio), Volumetric BOD loading, Mixed liquor suspended solids (MLSS), Sludge production rate, Sludge wasting, Return sludge ratio, Sludge volume index (SVI), oxygen/Air required for aeration and Nutrients requirements.

The kinetic model development on which the computer code is constructed is anchored on the principles of Monod's equation for microbial growth rate, biomass and substrate mass balances. The detail of this model is contained in the algorithm presented in Section 4 and they are found in literature (Tchobanoglous and Others, 2003).

Effect of Changing Temperature on CMAS Process: The Algorithm

The algorithm provided below is developed for a Visual Basic computer program to determine the effect of changing temperature on completely- mixed activated sludge process for BOD removal only. The temperature range considered is from 12 to 39 degree Celsius.

1.   Obtain influent wastewater characterization data.
2.   Calculate bCOD, nbCOD, and $sCOD_e$.

$$bCOD = 1.6 * BOD$$

$$nbCOD = COD - bCOD$$

$$sCOD_e = sCOD - 1.6 * sbBOD$$

3. Calculate nbVSS and iTSS.

$$nbVSS = \left[1 - \frac{(bCOD/BOD)*(BOD-sBOD)}{(COD-sCOD)}\right]*VSS$$

4. Input starting temperature.
5. Is the temperature greater than 40 $^\circ$C?
6. If yes, go to step 19.
7. Determine k_d and μ_m at the operating temperature.

$$k_d(T) = k_{d20}\theta_{kd}{}^{(T-20)}$$

$$\mu_m(T) = \mu_{m20}\theta_m{}^{(T-20)}$$

8. Calculate substrate reactor effluent concentration S.

$$S = \frac{K_s[1+(k_d)SRT\ ]}{SRT\ (\mu_m - k_d) - 1}$$

9. Calculate rate of production of volatile suspended solid $P_{X,VSS}$ and total suspended solids, $P_{X,TSS}$ in the reactor.

$$P_{XVSS} = \frac{QY(S_o-S)}{1+(k_d)SRT} + \frac{(f_d)(k_d)(S_o-S)SRT}{1+(k_d)SRT} + Q*nbVSS$$

$$P_{XTSS} = \left[\frac{QY(S_o-S)}{1+(k_d)SRT} + \frac{(f_d)(k_d)(S_o-S)SRT}{1+(k_d)SRT}\right]/0.85 + Q*nbVSS + Q*(TSS_o-VSS_o)$$

10. Calculate mass of VSS and TSS in the reactor.

$$mass\ of\ VSS = P_{XVSS}*SRT$$

$$mass\ of\ TSS = P_{XTSS}*SRT$$

11. Select a design MLSS concentration and determine the reactor volume, V and hydraulic detention time, τ.

$$V = \frac{P_{XTSS}*SRT}{MLSS}\quad and \quad \tau = \frac{Q}{V}$$

12. Determine MLVSS and observed yield.

$$MLVSS = \frac{mass\ VSS}{mass\ TSS}*MLSS$$

$$Y_{obsTSS} = 1.6*\frac{P_{XTSS}}{Q*(S_o-S)}\quad and \quad Y_{obsVSS} = 1.6*Y_{obsTSS}*\frac{mass\ VSS}{mass\ TSS}$$

13. Determine food to micro-organism ratio F/M.

$$F/M = \frac{Q*S_o}{X*V}$$

14. Determine volumetric BOD loading.

$$BOD\ loading = \frac{Q*S_o}{V}$$

15. Calculate the oxygen required.

$$R_o = Q*(S_o - S) - 1.4P_{Xbio}$$

$$P_{Xbio} = \frac{QY(S_o - S)}{1 + (k_d)SRT} + \frac{(f_d)(k_d)(S_o - S)SRT}{1 + (k_d)SRT}$$

$$R_o = SOTR$$

16. Determine air required

$$(AOTR) = (SOTR)(\alpha)(F)(1.024^{T-20}) \frac{\beta C_{STHav} - C_L}{C_{S,20}}$$

$$\beta = \frac{\text{saturation concentration in wastewater}}{\text{saturation concentration in clean water}}$$

$$C_{STHav} = (C_{STH}) \frac{1}{2}\left(\frac{P_d}{P_{atm,H}} + \frac{O_t}{21}\right), \quad C_{STHav} = (C_{STH})\left(\frac{P_{atm,H} + P_{w,mid\ depth}}{P_{atm,H}}\right)$$

$$(C_{ST})_{760} = \frac{475 - 2.65*S}{33.5 + T} \qquad C_{ST,H} = (C_{ST})_{760}\frac{P - P^{sat}}{760 - P^{sat}}$$

17. Increase temperature by 3.
18. Go to step 5.
19. Print temperature, aerator volume, hydraulic retention time, F/M ratio, sludge production rate, and air required.
20. Stop

In this algorithm, steps 5, 6, and 18 seem to control the temperature effect evaluation in the design process. This arrangement offers some advantage of designing at various temperatures instead of a fixed temperature which is achievable by ignoring the 3 steps stated.

The graphical representation of the algorithm on the effect of temperature on Activated sludge process for BOD removal only is presented in Figure 2

Development of Computer Code, ASP-SIM

The algorithm was developed into computer code written in Microsoft Visual Basic 6.0 and named: Activated Sludge Process Simulator, ASP-SIM (Adamu, 2007). Visual Basic is an interpreted programming language. It is currently among the most popular computer languages in the world because of the ease with which it can be learned and applied particularly for development of short- to medium-sized programs. Visual Basic shares many computational advantages of FORTRAN such as long variable names, double precision and adequate libraries of mathematical functions (Jonnes, 2001; Holzner,2004). The computer code was developed for Activated sludge process for BOD removal only, with option to determine the effect of temperature on the process. The computer program listing is presented in the Appendix.
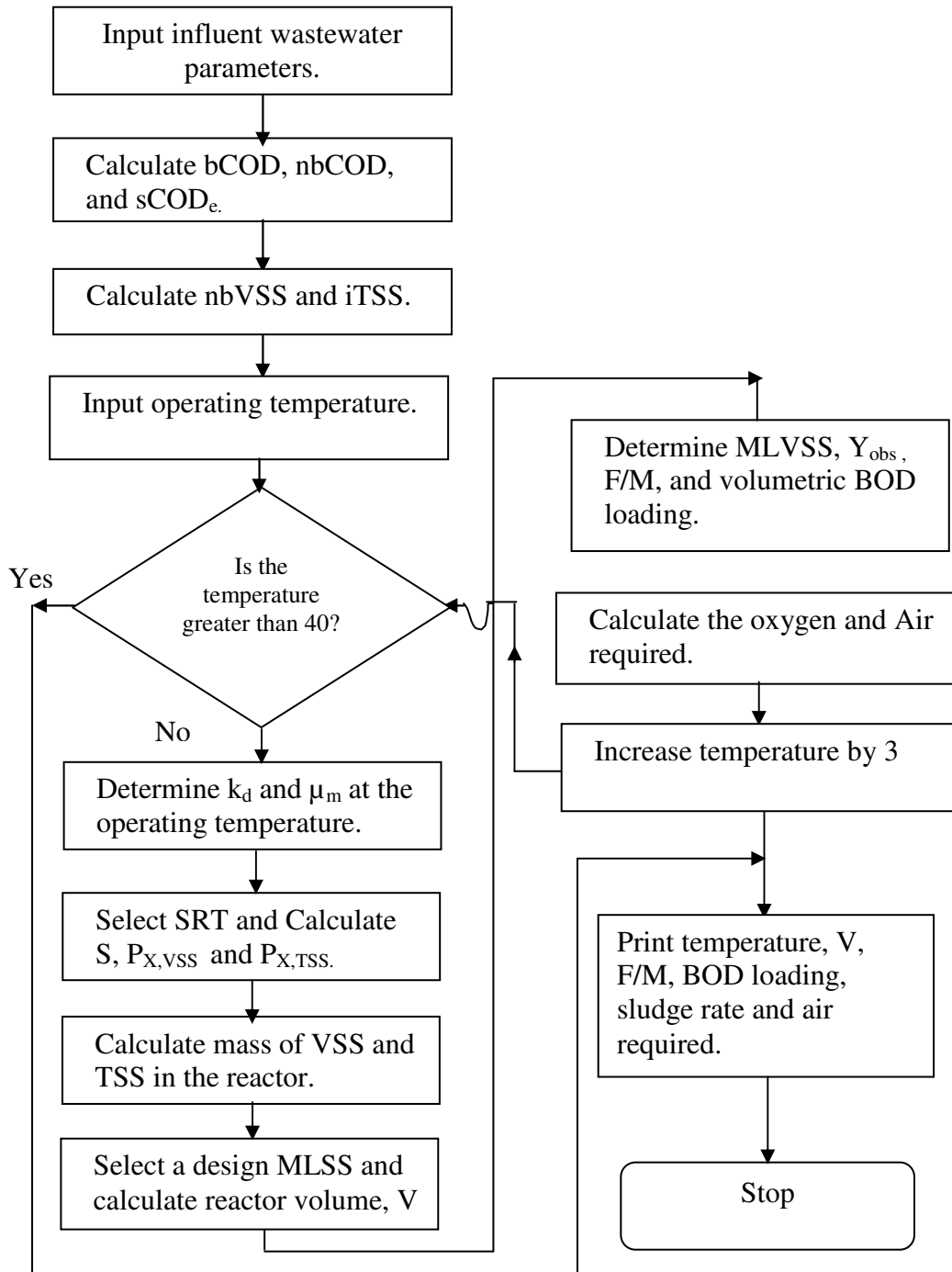
Input influent wastewater parameters.

Calculate bCOD, nbCOD, and $sCOD_e$.

Calculate nbVSS and iTSS.

Input operating temperature.

Is the temperature greater than 40?

Yes

No

Determine k_d and μ_m at the operating temperature.

Select SRT and Calculate S, $P_{X,VSS}$ and $P_{X,TSS}$.

Calculate mass of VSS and TSS in the reactor.

Select a design MLSS and calculate reactor volume, V

Determine MLVSS, Y_{obs}, F/M, and volumetric BOD loading.

Calculate the oxygen and Air required.

Increase temperature by 3

Print temperature, V, F/M, BOD loading, sludge rate and air required.

Stop

Figure 2: Flow chart for determination of effect of changing temperature on CMAS Process for BOD removal only.

MODEL EVALUATION

The computer program was modified to accommodate a fixed temperature of 12 ^{o}C for design problem taken from standard text book on Wastewater Engineering -Treatment and Reuse. (Tchobanoglous and Others, 2003). The code was thereafter tested to determine the effect of temperature on design of CMAS process for BOD removal.

Test problem

Design a complete-mix activated sludge (CMAS) process to treat 22,464 m^3/d of primary effluent to; (a) meet a BOD effluent concentration less than 30 g/m^3; and (b) Accomplish BOD removal and nitrification with an effluent NH4-N concentration of 0.5 g/m^3 and BOD effluent and TSS effluent less than 15 g/m^3. Compare the two design conditions in a summary table. The aeration basin mixed-liquor temperature is 12 ^{o}C. The following wastewater characteristics and design conditions apply: BOD=140 g/m^3, sBOD=70 g/m^3, COD=300 g/m^3, sCOD=132 g/m^3, rbCOD=80 g/m^3, TSS=70 g/m^3, VSS=60 g/m^3, TKN=35 g/m^3, NH_4-N=25 g/m^3, TP=6 g/m^3, Alkalinity=140 g/m^3 as $CaCO_3$ and bCOD/BOD ratio=1.6.

Design conditions and assumptions:
- (i).   Fine bubble ceramic diffuses with an aeration clean water O_2 transfer efficiency = 35%
- (ii).   Liquid depth for the aeration basin = 4.9 m
- (iii).   The point of air release for the ceramic diffusers is 0.5m above the tank bottom.
- (iv).   Dissolved oxygen in aeration basin = 2.0 g/m^3
- (v).   Site elevation is 500m (pressure = 95.6 kPa)
- (vi).   Aeration factor, α = 0.5 for BOD removal only and α = 0.65 for nitrification; β = 0.95 for both conditions and diffuser fouling factor, F = 0.90
- (vii).   SRT for BOD removal = 5d
- (viii).   Design MLSS concentration = 3000g/m^3; values of 2000 to 3000 g/m^3 can be considered.
- (ix).   TKN peak/average factor of safety, FS = 1.5
- (x).   Use kinetics coefficients given in Tables A-1 and A-2 in the Appendix. (Source: Tchobanoglous and others, 2003)

Entering input data: Data can be entered into text boxes or input boxes as the case may be.
Solution to test problem part (a) BOD removal only.

The input data for this test problem consists of the wastewater flow rate, the mix liquor suspended solids, the wastewater characteristics and the kinetic coefficients presented in Table A-1 in the Appendix. The results obtained are compared to that in the Literature and presented in Table 2.

Table 2: Comparison of literature and computer simulated results for CMAS process for BOD removal only.

Design Parameter	Units	SOLUTION		% diff.
		Literature	Computer simulated	
		BOD removal only (part A)	BOD removal only (part A)	
Aeration tank volume	m^3	4020 (1340 x 3 tanks)	4021.29 (1340.3 x 3 tanks)	-0.03
Hydraulic detention time	hr	4.3	4.3	0.00
F/M ratio	kg/kg.d	0.33	0.33	0.00
BOD loading	kg BOD/m^3.d	0.78	0.78	0.00
Sludge production	kg/d	2413	2412.77	0.009
Air required	m^3/min	55.5	55.63	0.23

The percentage difference between computer simulated results and that of literature are very negligible (from 0.00 to -003 for the first five parameters and 0.23 for the last parameter). The reason for the margin of error of 0.23 is due to the slight variation of method used for

determination of concentration of dissolved oxygen at saturation. In effect the computer code is error free and can be used for design purposes.

On the effect of temperature on CMAS process, the temperature on the existing test problem was varied from 12 to 39 $^\circ$ C. The computer code (ASP-SIM) was employed to simulate the design parameters such as aerator volume, F/M ratio, BOD loading, sludge production rate and air requirement. The results are as presented in Table 3. Also the graphical representations of the results are as presented in Figures 3 and 4. The effect of temperature on both volume and sludge production rate is that of an inverse relationship. It shows a decrease in volume/sludge production rate as temperature increases. On the other hand, direct proportional relation exists between temperature and air requirement (see Figure 4).

Table 3: Effect of temperature on CMAS process design variables for BOD removal only.

| Temp(deg. C)	V (m^3)	F/M (g/g.d)	BOD loading (kgBOD/m^3.d)	Sludge production (kg/d)	Air required (m^3/min)
12	4021.29	0.33	0.78	2412.77	55.63
15	3941.48	0.33	0.80	2364.89	57.73
18	3856.94	0.34	0.82	2314.16	59.68
21	3768.39	0.35	0.83	2261.03	61.49
24	3676.55	0.36	0.86	2205.93	63.17
27	3582.15	0.37	0.88	2149.40	64.71
30	3485.94	0.38	0.90	2091.57	66.10
33	3388.69	0.39	0.93	2033.22	67.36
36	3291.15	0.40	0.96	1974.69	68.47
39	3194.06	0.42	0.98	1916.43	69.43
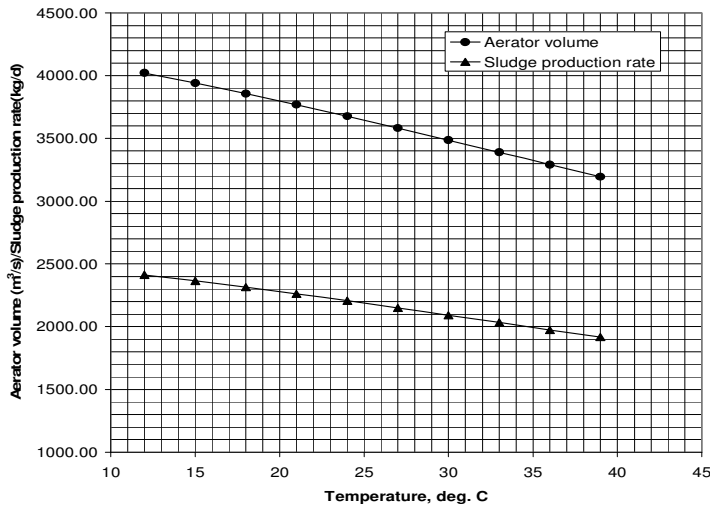
Figure 3: Effect of temperature on reactor volume and sludge production rate for CMAS Process design.
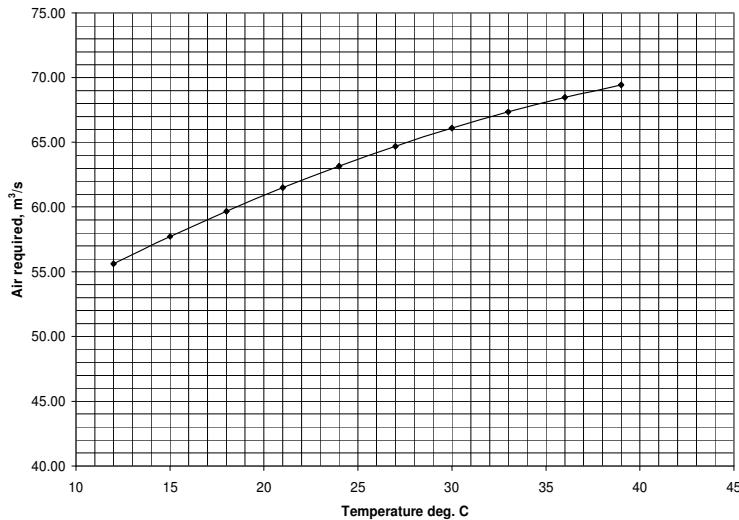
Figure 4: Effect of temperature on air required for CMAS process design.

CONCLUSION

The computer program ASP-SIM written in visual basic 6.0 is a very handy tool in the design of wastewater treatment plant using activated sludge process. Ordinarily, this type of design is manually done, consumes time and margin of error in computation due to approximation can be enormous. Visual Basic code as adopted in ASP-SIM is user friendly, parameters can be change at will to accommodate design conditions. The results presented in graphical form will serve as a quick reference material for predicting the effect of temperature on the design and operation of completely mixed activated sludge process for BOD removal.

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APPENDIX

(A) Kinetic coefficients for activated sludge process. The kinetic coefficients in Table A-1 are to be used for the design of activated sludge process for removal of carbonaceous material (based on bCOD) by heterotrophic bacteria.

Table A-1: Activated sludge kinetic coefficients for heterotrophic bacteria at 20 ^{o}C

Coefficient	Unit	Range	Typical value
μ_m	gVSS/gVSS.d	3.0 - 13.2	6.0
K_s	gbCOD/m^3	5.0 - 40.0	20.0
Y	gVSS/gbCOD	0.30 – 0.50	0.40
k_d	gVSS/gVSS.d	0.06 – 0.20	0.12
f_d	unitless	0.08 – 0.20	0.15
θ values			
μ_m	unitless	1.03 – 1.08	1.07
k_d	unitless	1.03 – 1.08	1.04
K_s	unitless	1.0	1.0

The kinetics coefficients in Table A-2 are to be used for design of nitrification with activated sludge by heterotrophic bacteria.

Table A-2: Activated sludge nitrification kinetic coefficients for heterotrophic bacteria at 20 ^{o}C

Coefficient	Unit	Range	Typical value
μ_{mn}	gVSS/gVSS.d	0.20 – 0.9	0.75
K_n	gNH$_4$-N/m^3	0.5 - 1.0	0.74
Y_n	gVSS/gNH$_4$-N	0.10 – 0.15	0.12
k_{dn}	gVSS/gVSS.d	0.05 – 0.15	0.08
K_o	g/m^3	0.40 – 0.60	0.50
θ values			
μ_n	unitless	1.03 – 1.08	1.07
K_n	unitless	1.03 – 1.08	1.053
k_{dn}	unitless	1.0	1.04

APPENDIX –B: COMPUTER CODE—CMAS-SIM LISTING

(B) Program written in visual basic 6.0 for determination of effect of changing temperature on CMAS process.

```
Private Sub Command_4 Click ()
'EFFECT OF CHANGING TEMPERATURE ON
CMAS PROCESS.
Form14.Show
Form14.Print "EFFECT OF CHANGING TEMPE
RATURE ON CMAS PROCESS." Form14.Print
"DESIGN OF THE ACTIVATED SLUDGE SYST
EM FOR BOD REMOVAL ONLY."
Form14.Print
Form14.Print "Temperature", "Volume", "F/M
ratio", "BOD loading", Spc(3); "Sludge production
", Spc(2); "Air required"
Form14.Print "Deg. C", "m3", "kg/kg.d",
"(kgBOD/m3.d)", "(kg/d)", "(m3/min)"
'WASTEWATER CHARACTERISTICS.
Dim bod, sbod, cod, scod, rbcod, tss, vss, tkn,
nh4n, tp, akalinity As Double
bod = Text1.Text: sbod = Text2.Text: cod =
Text3.Text: scod = Text4.Text:
rbcod = Text5.Text: tss = Text6.Text: vss =
Text7.Text:
tkn = 35: nh4n = 25: tp = 6: akalinity = 140:
Dim r22, scode, bcod, nbcod, nbvss, itss, so As
Double
r22 = 0: scode = 0: bcod = 0: nbcod = 0: nbvss =
0: itss = 0: so = 0:
'CALCULATE WASTEWATER CHARACTERISTI
CS NEEDED FOR THE DESIGN.
bcod = 1.6 * bod
nbcod = cod - bcod
scode = scod - 1.6 * sbod
r22 = ((bcod / bod) * (bod - sbod)) / (cod - scod)
nbvss = (1 - r22) * vss
itss = tss - vss
so = bcod
Dim um, umt, thetaum, kd, kdt, thetakd, temp1,
temp, srt, s, ks As Double
um = Text12.Text: umt = 0: thetaum = 1.07: kd =
Text10.Text: kdt = 0: thetakd = 1.04:
temp1 = 0: temp = Text9.Text: srt = Text13.Text:
s = 0: ks = Text11.Text:
Do While temp <= 40
temp1 = temp - 20
umt = um * thetaum ^ temp1
kdt = kd * thetakd ^ temp1
s = ks * (1 + kd * srt) / (srt * (umt - kdt) - 1)
Dim pxvss1, pxvss, pxtss, q, y, fd As Double
pxvss1 = 0: pxvss = 0: pxtss = 0: q = Text8.Text:
y = 0.4: fd = 0.15:
pxvss1 = ((q * y * (so - s) / (1 + kdt * srt)) + (q * fd
* kdt * y * (so - s) * srt / (1 + kdt * srt))) / 1000
pxvss = ((q * y * (so - s) / (1 + kdt * srt)) + (q * fd *
kdt * y * (so - s) * srt / (1 + kdt * srt))) / 1000 + q *
nbvss / 1000
pxtss = pxvss1 / 0.85 + q * nbvss / 1000 + q * (tss
- vss) / 1000
```

```
Dim massvss, masstss, mlss, v, tau, mlvss As
Double
massvss = 0: masstss = 0: mlss = Text14.Text: v
= 0: tau = 0: mlvss = 0:
massvss = pxvss * srt
masstss = pxtss * srt
v = pxtss * srt * 1000 / mlss
tau = v * 24 / q
mlvss = (massvss / masstss) * mlss
Dim fmratio, yobtss, yobvss, bodloading As
Double
fmratio = 0: yobtss = 0: yobvss = 0: bodloading =
0:
fmratio = (q * bod) / (mlvss * v)
bodloading = (q * bod) / (v * 1000)
yobtss = (pxtss * 1000 * 1.6) / (q * (so - s))
yobvss = (pxvss * 1000 * 1.6) / (q * (so - s))
Dim ro1, ro As Double
ro1 = 0: ro = 0:
ro1 = (q * (so - s)) / 1000 - 1.42 * pxvss1
ro = ro1 / 24
Dim csth, pd, patm, g, molarmass, zb, za, r As
Double
Dim pb, pa, tempk, dos, dsolids, density, h As
Double
g = 9.81: molarmass = 28.97: zb = 500: za = 0: r
= 8314
pa = 760: dos = 0: dsolids = 0: h = 0
If temp < 15 Then
density = 999.833
ElseIf temp >= 15 Then
density = -0.0032 * temp ^ 2 - 0.1204 * temp +
1001.9
End If
tempk = 273.15 + temp
h = -g * molarmass * (zb - za) / (r * tempk)
pb = pa * Exp(h)
pbn = 101325 * Exp(h)
patm = pbn / (density * g)
Dim liquiddepth, airreleasedepth, ot, doaeration
As Double
liquiddepth  =4.9:  airreleasedepth  =  0.5:
doaeration = 2
effectivedepth = liquiddepth - airreleasedepth
Dim aotr, sotr, beta, alpha, csthav, cl, cs20, F As
Double
alpha = 0.5: F = 0.9: beta = 0.95: cs20 = 9.08
aotr = ro
cl = doaeration
ot = 21 - doaeration
csth = (((pb - 17.55) / (760 - 17.55)) * ((475 - 2.65
* dsolids) / (33.5 + temp))) + 0.2659
csthav = 0.5 * csth * ((patm + effectivedepth) /
patm + (ot / 21))
Dim denum1, num1, temp22 As Double
temp22 = 0
```

```
temp22 = 20 - temp
denum1 = alpha * F * (beta * csthav - cl)
num1 = (1.024) ^ temp22
sotr = (aotr * cs20 * num1) / denum1
Dim  airflowratem,  airflowratev,  efficiency,
densityair As Double
Dim densityox, oxflowrate As Double
densityox = 0
oxflowrate = 0
densityair = 0
airflowratem = 0
airflowratev = 0
efficiency = 0.35
densityair = (pbn * molarmass) / (r * tempk)
densityox = (pbn * 32) / (r * tempk)
oxflowrate = sotr / (efficiency * 60 * densityox)
airflowratev = oxflowrate * (100 / 21)
'Estimation of the effluent BOD.
Dim bodef, sbodef, tsse As Double
bodef = 0: sbodef = 3: tsse = 10:
bodef = sbodef + 0.85 * (tsse / 1.42)
'SECONDARY CLARIFIER DESIGN
Dim rasr, qr, xr, solidloading, area As Double
rasr = 0: qr = 0: xr = 8000: solidloading = 0: area
= 0
rasr = mlss / (xr - mlss)
qr = rasr * q
'Assumed  return  sludge  concentration  xr  =
800mg/l
Dim  hydraulicapprate, area2, area3, diameter,
diameter2 As Double
hydraulicapprate = 22: area3 =0:diameter = 0:
area2 = 0
diameter2 = 0
'Assume hydraulic application rate of 22m3/m2.d
area = q / hydraulicapprate
area3 = area / 3
diameter2 = (area3 * 4 / 3.142) ^ 0.5
diameter = Int(diameter2)
area2 = (3.142 / 4) * (diameter ^ 2)
'Use three clarifiers, one for each aeration tank.
'Check solid loading
solidloading = ((q + qr) * mlss / 1000) / (3 * area2
* 24)
Form14.Print  Format(temp,  "##.0");  Spc(0),
Format(v,  "####.00"),  Format(fmratio,  "0.00");
Spc(5),  Format(bodloading,  "0.00"),  Spc(1),
Format(pxtss,  "####.00"),  Format(airflowratev,
"####.00")
temp = temp + 3
Loop
End Sub
```