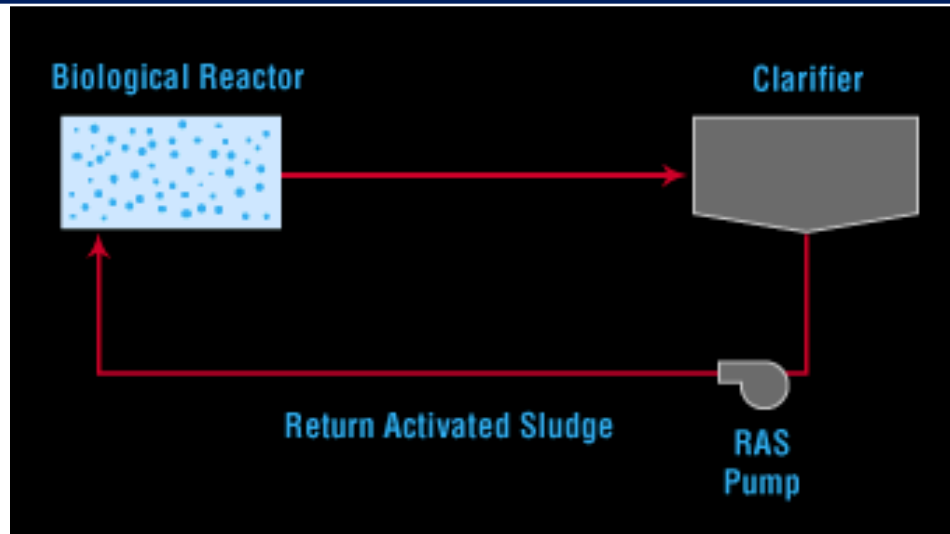


# Bio-Tiger Model User Manual



**Bio-Tiger Model – Biokinetic Model  
that Simulates Activated Sludge Processes**

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## **IMPORTANT NOTICE**

The Bio-Tiger model was developed by Dr. Moore and his graduate students to simulate activated sludge processes. Dr. Moore has used this model (and previous versions of it) to analyze approximately 100 activated sludge processes throughout the U.S. In general, the model is very useful for making process decisions to optimize the activated sludge process, to achieve energy savings via better aeration system control, and to improve effluent quality (especially in terms of effluent Total Nitrogen reduction).

The contents of this manual are for general guidance only and are not intended to be a standard of the State of Tennessee or the federal government. No reference in this manual to any specific method, product, process, or service constitutes or implies an endorsement or warranty by the University of Memphis, the State of Tennessee, the U.S. Department of Energy (USDOE), or the U.S. Environmental Protection Agency (USEPA). This manual reflects the best judgment of the author, but the University of Memphis, the State of Tennessee, the USDOE, and the USEPA assume no liability for implementation of the information contained herein. Anyone using this information assumes all liability arising from such use, including but not limited to infringement of any patent or trademarks and compliance with applicable state and federal regulations.

## **I. Introduction**

The Bio-Tiger model is set up to provide the user an opportunity to evaluate the activated sludge process at existing conditions as well as at conditions defined for an alternate operating scenario. Typical alternate scenarios that may be evaluated include, but are not limited to, process design conditions, use of alternative aeration equipment, use of alternative operating dissolved oxygen (DO) concentrations in the reactor, impact of changes in influent loadings as a result of a new industry, impact of turning aerators off to achieve denitrification, and so on.

Using basic process data and equipment information, the model can help the user determine, among other things:

- The oxygen requirements of the biological process
- The oxygen supplied by aeration equipment
- The quantity and cost of energy consumed by the aeration equipment
- Whether another operating strategy would allow the aeration system to meet the present (or future) oxygen demand more efficiently
- Whether an aeration system is being used to efficiently meet the oxygen demands of the biological process, and if another operating scenario could produce cost savings

Changing the operating conditions of an activated sludge process could have significant impacts on plant performance and effluent quality. Thus, it is advisable to seek input from the city's engineer, consultant, or plant manager prior to implementing the change. The model provides very good information about activated sludge process performance when alternate operating strategies are being considered. Still, it would be beneficial to have input from the utility's management prior to implementing process changes. Moreover, it may also be useful to alert appropriate state regulatory agency personnel prior to making changes to process operations; their input may be very valuable.

To assess current conditions, in most cases it is best to use at least 12 months of historical influent data and 12 months of specific activated sludge process data. For biokinetic constants, the user should use values suggested by Metcalf & Eddy and/or by Dr. Moore. If operational conditions vary seasonally (because of seasonal permit limits or seasonal changes due to tourism, academic schedules, operator discretion, etc.), then it may not be practical to assess the biological treatment process using annual average conditions. In this case, it is advisable to create a separate copy of the model for each set of seasonal conditions. In general, the biokinetic

constant values recommended by Dr. Moore are consistent with the values recommended by Metcalf & Eddy. Should the user elect to enter user-defined values, please be aware that it is important to use biokinetic constant values that are within recommended ranges. However, if one uses the model to evaluate an activated sludge process for an industrial wastewater, then it may indeed be desirable to use values outside the recommended ranges. The user just needs to be very careful in selecting the appropriate biokinetic constants for a given specific wastewater source.

The Bio-Tiger Model is based on biokinetic equations that are given in the book, Wastewater Engineering Treatment and Reuse (4<sup>th</sup> edition, 2003) by Metcalf & Eddy. These equations are based on Monod kinetics and mass balances around the activated sludge process or around the reactor of the activated sludge process. Some assumptions of the model are:

- No reactions in the secondary clarifier
- No reactions in the sludge recycle line
- Biomass in the influent is negligible
- Steady state conditions
- Completely mixed reactor
- Influent substrate concentration (BOD<sub>5</sub>) is primarily in soluble form
- No accumulation of biomass in the secondary clarifier

The equations used in the Bio-Tiger model are protected – that is, the user does not have access to the equations and cannot change or manipulate the equations. Dr. Moore has spent a considerable amount of time over the last few years making sure that the equations are accurate and representative of the activated sludge process. Moreover, it is incumbent on the user to make sure that accurate data are provided for the activated sludge process being evaluated. Influent wastewater flow rate, influent wastewater characteristics, reactor volume, solids concentrations (MLSS, RAS TSS, effluent TSS), and biokinetic constants must be accurately defined to produce meaningful results using the Bio-Tiger model.

## II. Bio-Tiger Model Activated Sludge Input Data

An example of the activated sludge input data for the model is provided below:

Activated Sludge Input Data	
Temperature (°C)	20
S <sub>o</sub> (mg/L CBOD5)	142
Volume of reactor (mil gal)	0.98
Influent flow rate, Q (mgd)	2.85
Inert VSS (mg/L)	40
Oxidizable N (mg/L)	25
biomass (VSS/TSS)	0.85
Influent TSS (mg/L)	214
Inert Inorganic TSS (mg/L)	20
Effluent TSS (mg/L)	5
RAS TSS (mg/L)	9300
MLSS (mg/L)	3800
<b>f<sub>d</sub></b>	<b>0.1</b>
<b>Y</b>	<b>0.6</b>
<b>K<sub>s</sub> (mg/L)</b>	<b>60</b>
<b>k<sub>d</sub> at 20°C (1/day)</b>	<b>0.1</b>
<b>k at 20°C (1/day)</b>	<b>8</b>

Except where noted, influent parameters refer to the values as measured immediately upstream of the activated sludge reactor, and downstream of any headworks or primary treatment.

**Temperature** is obviously very important because temperature impacts the rate of microbial reactions. The biokinetic constants,  $k_d$  and  $k$ , will be adjusted by model calculations according to the input temperature. Thus, the input values for these two biokinetic constants must be at 20 °C.

The term “ $k_d$ ” is the endogenous decay coefficient; it determines the rate that the microbes oxidize their own protoplasm to generate energy. At warmer temperatures, the endogenous respiration rate (and hence  $k_d$ ) increases. As a result, under winter conditions less oxygen will be required for the activated sludge process, but sludge (biomass) production will increase. Conversely, under summer conditions more oxygen will be required for the activated sludge process, but sludge (biomass) production will decrease.

**The term “ $k$ ”** is the maximum specific substrate utilization rate; it determines the rate at which the heterotrophic bacteria use biodegradable organic matter. Organic matter is used primarily for two purposes by bacteria – synthesis (growth) reactions and energy (oxidation) reactions. Synthesis reactions create bacterial cell mass, primarily through binary fission. It should be noted that at low solid retention times (SRTs) most of the influent biodegradable organic loading will be used for synthesis reactions. At longer SRTs most of the influent biodegradable organic loading will be used for energy reactions.

**The term “ $S_o$ ”** is the concentration of  $CBOD_5$  that enters the activated sludge reactor. In other words, the growth limiting substrate in the Bio-Tiger model is  $CBOD_5$ . Defining “ $S_o$ ” accurately is absolutely critical in terms of producing model results in which the user can have good confidence. Obviously, the influent  $CBOD_5$  concentration changes during the day and throughout the week. Thus, the input value should represent the “average”  $CBOD_5$  concentration for the particular activated sludge process being evaluated. Remember, this is a steady-state model!

**The volume ( $V$ )** of the reactor should be in million gallons. If the aerobic reactor is preceded by an anaerobic reactor and/or anoxic reactor, it is usually best to use the total (anaerobic/anoxic/aerobic) reactor volume for the model simulation.

**The flow rate ( $Q$ )** to the reactor is the influent flow rate in million gallons per day (mgd). Thus,  $Q$  does not include the return activated sludge (RAS) flow rate, and detention time calculations for the reactor(s) are based only on activated sludge influent flow rate.

**The term “inert VSS”** is a very important parameter related to the characteristics of the activated sludge influent. VSS represents the volatile suspended solids in the activated sludge influent. Inert VSS represents the incoming suspended organic material that is essentially non-biodegradable. Inert VSS in the influent is very important because it will typically have a significant impact on total sludge production in the activated sludge process. In other words, the influent inert VSS will not be degraded in the process and, thus, will eventually end up in the solids leaving the process.

***Oxidizable nitrogen (N)*** in the activated sludge influent is also a very important input parameter for the model. In most cases, the oxidizable N will be the Total Kjeldahl Nitrogen (TKN) concentration of the activated sludge influent. The model assumes that most of the organic N in the activated sludge influent will be readily hydrolyzed to ammonia-N in the process. The model will calculate the concentration of influent nitrogen that is incorporated in biomass production. Most of the remaining influent nitrogen will become effluent ammonia-N and effluent nitrate-N, if the process has a sufficiently long SRT and is not operated to achieve significant denitrification. Typically, effluent dissolved organic N will be relatively low (often 1 mg/L or less), unless the activated sludge process receives significant loadings of inert dissolved organic N (e.g. certain amine groups from pulp, paper, paperboard, and cellulose production processes).

Biological nitrification converts ammonia-N to nitrite-N and then to nitrate-N. In the model, nearly all of the ammonia-N that is converted to nitrite-N will be subsequently converted to nitrate-N. In activated sludge processes, a problem with the buildup of significant concentrations of nitrite-N (i.e., “nitrite lock”) can occur under some unusual circumstances. In the Bio-Tiger model, the buildup of significant concentrations of nitrite-N is not considered.

The oxidation of ammonia-N to nitrate-N (nitrification) is handled relatively simply in the Bio-Tiger model. Biokinetic equations **are not used** to predict the degree of nitrification in the process. It should be noted that several factors affect the nitrification rate in the activated sludge process. They are listed below:

- Type of reactor (plug flow or complete-mix)
- SRT
- Dissolved oxygen (DO)
- Temperature
- pH
- Ammonia-N concentration
- Impact of inhibitory substances

The Bio-Tiger model uses empirically derived curves that determine the degree of nitrification based on the solids retention time (SRT) of the activated sludge process. The Bio-Tiger model uses three different curves for nitrification efficiency versus SRT based on data from actual activated sludge processes. One curve is for mixed liquor temperatures less than 15 °C; one curve is for mixed liquor temperatures between 15 °C and 24 °C; and one curve is for mixed liquor temperatures above 24 °C. It should be noted that the nitrification curves in the model typically slightly under-predict the degree of nitrification. In other words, the effluent ammonia-N concentration is usually predicted slightly higher than what the activated sludge process will likely yield in the field. Nevertheless, based on Dr. Moore’s experience, this approach results in a reasonably good estimation of the process.

As in the Metcalf & Eddy book, the *VSS/TSS ratio* of the biomass is estimated to be 0.85. The user may change this ratio, but the value used should normally be in the range of 0.80 to 0.90. Dr. Moore almost exclusively uses the 0.85 value. This parameter should not be confused with the ratio of MLVSS to MLSS, which decreases as SRT increases, due to oxidation of the biomass during endogenous respiration.

The *influent TSS* concentration is important, and is primarily used to calculate the mass loading of TSS on the activated sludge process.

The *inert inorganic TSS* concentration entering the activated sludge process is very important because (like the inert VSS) the inert inorganic TSS concentration also has a significant impact on solids production. A significant portion of inorganic TSS is inert and will eventually end up in the solids leaving the process. The guidelines for selecting the inert VSS and inert inorganic TSS of the influent are based on the influent TSS concentration. This decision is left entirely to the user. However, it is essential that reasonable values be selected for any model simulation. The suggested guidelines are noted below:

<u>Influent TSS concentration, mg/L</u>	<u>Inert VSS, mg/L</u>	<u>Inert Inorg. TSS, mg/L</u>
100	20	10
150	30	15
200	40	20
250	50	25
300	60	30

*Effluent TSS* concentration is very important and must be specified by the user. Effluent TSS (mass loading) is known as “unintentional solids wasted.” Thus, the effluent TSS mass loading is important in calculating SRT for the process. Moreover, effluent TSS will be used to calculate the suspended or “chunky” CBOD<sub>5</sub> of the effluent. It should be noted that the fraction of the effluent TSS that is biodegradable will decrease with increasing SRT. Therefore, the suspended CBOD<sub>5</sub> will decrease with increasing SRT for the same effluent TSS concentration. The total CBOD<sub>5</sub> of the effluent is the “chunky” effluent CBOD<sub>5</sub> plus the soluble effluent CBOD<sub>5</sub>.

*RAS TSS* concentration is also very important because it is used to determine the RAS flow rate and the WAS flow rate for activated sludge. Typically, RAS TSS will be in the range of 4,000 to 15,000 mg/L, but it can be outside this range in some plants.

The user must specify the *MLSS concentration* for the activated sludge process. Typically, MLSS concentration will be in the range of 1,000 mg/L to 5,000 mg/L. However, MLSS values



outside this range are possible. If your system has more than one reactor, the MLSS concentration may be slightly different in each reactor. In this case, select the “average” MLSS concentration for the reactors.

**The term “ $f_d$ ”** is the fraction of biomass that remains as cell debris. The typical range for “ $f_d$ ” is 0.10 to 0.15. Cell debris is a small component of biomass production, but it is included because it impacts biomass production and oxygen requirements.

**The term “ $Y$ ”** is the biomass yield constant. The typical range for this parameter is 0.4 to 0.8. It impacts biomass production, substrate utilization, and oxygen requirements. It is the theoretical (gross) yield of biomass per unit CBOD<sub>5</sub> consumed. The “net” yield of biomass depends on  $k_d$  and SRT; the net yield decreases as  $k_d$  increases and as SRT increases.

**The term “ $K_s$ ”** is the half saturation constant. The typical range for this parameter is 25 to 100 mg/L. It impacts substrate (CBOD<sub>5</sub>) utilization and biomass growth.

**The term “ $k_d$ ”** is the endogenous decay coefficient. The typical range for this parameter at 20 °C is 0.06 to 0.15 day<sup>-1</sup>. It impacts biomass production, substrate utilization, and oxygen requirements. This parameter will be adjusted in the model calculations based on temperature.

**The term “ $k$ ”** is the maximum specific substrate utilization rate. The typical range for this parameter at 20 °C is 3 to 16 day<sup>-1</sup>. It impacts biomass production, substrate utilization, and oxygen requirements. This parameter will be adjusted in the model calculations based on temperature.

### **III. Bio-Tiger Model Aerator Performance Input Data**

The model gives the user the opportunity to evaluate the performance of specific aeration equipment used in the activated sludge process. As noted in the “Introduction,” examining different aeration strategies may lead to increased aeration efficiency, reduced energy use in kWh per month, reduced energy costs, more efficient denitrification, and other process improvements.

An example of aerator performance input data for *existing conditions* is provided below:

Aerator Performance Data	
Operating DO concentration (mg/L)	3.5
alpha	0.84
beta	0.92
SOTR, lb O <sub>2</sub> / hp-hr	3.1
Temperature (°C)	20
Aeration (hp) being operated	255
Elevation (ft)	400
Aerators operating time (hr/day)	24
Type of aerators (1, 2, or 3)	2
Speed of aerators (%)	70
Energy cost unit (\$/kWh)	0.055

**Operating DO concentration** is extremely important because it impacts biological metabolism as well as performance of the aeration equipment. In most cases where aerobic metabolism is desired for removal of CBOD<sub>5</sub> and ammonia-N, the operating DO concentration should be in the range of 0.5 to 1.5 mg/L. If simultaneous nitrification/denitrification is desired, the operating DO concentration should be in the range of 0.0 to 0.3 mg/L.

In terms of aeration equipment performance, a lower DO concentration will enhance the field oxygen transfer rate of aerators. In the example above, a 255-hp positive placement blower running 24 hours per day at 70% speed is used to maintain an operating DO concentration of 3.5 mg/L in the aeration basins (using fine-bubble diffusers). Compared to operating at a DO concentration of 2.0 mg/L, the aeration equipment is 24% less efficient in terms of the field oxygen transfer rate (OTR). In the example above, the operating DO (3.5 mg/L) is higher than the aforementioned desired range of 0.5 to 1.5 mg/L. Thus, one option for energy savings at this plant is to run the blower at a lower speed and reduce the DO concentration in the aeration basins.

The term **alpha** is the oxygen transfer coefficient in wastewater divided by the oxygen transfer coefficient in tap water. The typical range of alpha for municipal wastewater is 0.8 to 0.9. Dr. Moore prefers to use a value of 0.84 for most municipal wastewaters.

The term **beta** is the saturation DO concentration in wastewater divided by the saturation DO concentration in tap water. The typical range of beta for municipal wastewater is 0.9 to 0.95. Dr. Moore prefers to use a value of 0.92 for most municipal wastewaters.

The term **SOTR (standard oxygen transfer rate)** is the oxygen transfer rate in tap water at 20 °C, zero DO concentration, and sea level conditions (one atmosphere of pressure). Aeration equipment manufacturers test their equipment at standard conditions to determine the **SOTR**. The design engineer must adjust the **SOTR** for field conditions. To determine the **Field OTR** for surface aerators, the following equation is used.

$$\text{Field OTR [lb/(hp-hr)]} = \frac{\text{SOTR} \times \{[(\beta\rho C_s) - C] \times (\alpha \times 1.024^{(T-20)})\}}{9.17}$$

where:

- $C_s$  = saturation oxygen level in clean water at the design altitude, mg/L
- $C$  = operating oxygen level in wastewater at the design altitude, mg/L
- $\alpha$  =  $O_2$  transfer coefficient in wastewater/  $O_2$  transfer coefficient in clean water
- $\beta$  =  $C_s$  in wastewater/ $C_s$  in clean water
- $\rho$  = correction factor for  $C_s$  at the given elevation
- $T$  = water temperature in °C

**SOTR** for surface aerators is expressed as lb/(hp-hr). The suggested value for **SOTR** for different types of aeration equipment is provided in the comment box for **SOTR** in the input data. Please note that standard oxygen transfer capacity for diffused aeration systems is typically expressed as a percent transfer efficiency. Therefore, for diffused aeration systems, percent transfer efficiency at standard conditions has been converted to lb/(hp-hr) by making the following assumptions:

- Compressor efficiency = 75%**
- Tank depth = 15 ft**
- Diffusers located 1.5 ft above tank bottom**

In reality, aeration tanks will not always be 15 feet deep. As the tank depth is increased, the oxygen transfer rate of diffused aeration systems will increase because the air bubbles will be exposed to the mixed liquor for a longer time as they rise in the reactor. On the other hand, the required blower pressure increases with increasing tank depth. *Therefore, the net effect on*

*oxygen transfer rate (lb/(hp-hr)) remains relatively constant for diffused aeration systems as depth increases.*

**Temperature** affects oxygen transfer rates in two ways. As temperature increases,  $C_s$  decreases – which tends to decrease **field OTR**. On the other hand, as temperature increases, the physical-chemical transfer of molecular oxygen across the gas-liquid film increases, which tends to increase **Field OTR**. Both of these components are incorporated in the equation above for calculating the **Field OTR**.

The **aeration horsepower being operated** must be provided by the user. Obviously, this is important input data used to calculate the total oxygen supplied to the reactor(s).

The **elevation (feet)** of the site impacts the saturation DO concentration. Using the user-specified site elevation, the model calculates  $C_s$  appropriately by adjusting the value of  $\rho$ .

**Aerators operating time (hr/day)** must be specified by the user. In many cases, aeration equipment will run 24 hours per day. In some cases, aeration equipment may run less than 24 hours per day (e.g. when the process is organically under-loaded or when using on-off aerator operation to achieve denitrification).

**Type of aerators** must be specified by the user. The three types of aeration equipment are mechanical aerators, positive displacement blowers, and centrifugal blowers. To conserve energy, it may be desirable to install variable frequency drives (VFDs) on aerators or blowers to modulate aerator or blower output. For mechanical aerators, oxygen supplied and power draw are assumed to be directly proportional to aerator speed. For positive displacement blowers, blower airflow and power draw are assumed to be directly proportional to blower speed. The power drawn by centrifugal blowers is calculated differently; it is based on “fan laws” for predicting performance of centrifugal blowers operating at variable speed. The power drawn by centrifugal blowers is equal to the power drawn at the original speed multiplied by [(new operating speed/original operating speed) raised to the third power]. Typically, mechanical aerators and positive displacement blowers can be operated at 50% to 100% speed. In many cases, centrifugal blowers can only be operated at 90% to 100% speed; otherwise, blower operation may be unstable. Manufacturers of centrifugal blowers should be consulted prior to installing VFDs on these blowers.

**Speed of aerators** in percent also must be specified by the user. Comments in the immediately preceding paragraph must be considered when determining the appropriate values for **speed of aerators**. VFDs can be used to control the speed of aeration equipment in many cases. Often aerator output will be controlled by VFDs receiving signals from the automatic DO control

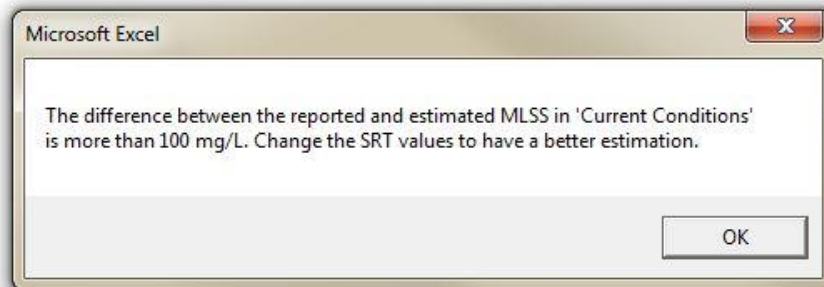
system. This is an excellent way to achieve energy conservation by matching aerator output to aeration demand.

**Energy cost unit (\$/kWh)** must be specified by the user. These rates will be determined by the electric power provider. **Energy cost unit** represents the total cost of electric energy including the base kWh charge, demand charge, fuel adjustment charge, environmental fee, administrative charge, power factor penalty, state and local taxes, and so on. The typical range for **energy cost unit** is \$0.05 to \$0.15 per kWh.

#### IV. Executing the Model and Assessing Model Results

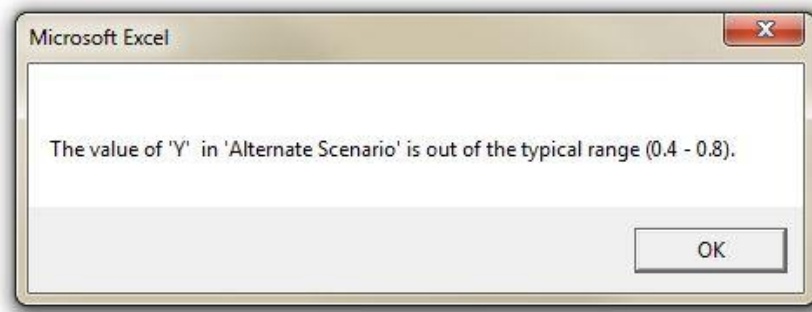
After all activated sludge input data discussed above are loaded into the model for “**Current Conditions**,” the user simply clicks the “**Analysis**” button to activate the biokinetic calculations of the model and to generate output data for **current operating conditions**. An “**Alternate Scenario**” set of activated sludge input data also is provided; the user changes the input data as desired for the alternate scenario. When the “**Analysis**” button is clicked, the model simultaneously calculates **approximate operating conditions** for “**Current Conditions**” and for the “**Alternate Scenario**.”

As the model processes the activated sludge input data, it attempts to match the “user specified MLSS concentration” with the “model calculated MLSS concentration.” If the “user specified MLSS concentration” is within 100 mg/L of the “model calculated MLSS concentration,” the model will immediately show the “**Output**” data for “**Current Conditions**” and for the “**Alternate Scenario**.” If the “user specified MLSS concentration” is **NOT** within 100 mg/L of the “model calculated MLSS concentration,” the model will immediately show the following message box:



To adjust the SRT value, one needs to click the “**OK**” box and then click the sheet tabs at the bottom of the page entitled “**Calculations Current**” and/or “**Calculations Alternate**.” Scan the MLSS values in Column H of the appropriate output table to get some idea of what the SRT needs to be by interpolating among the various MLSS values in Column H. The goal is to choose an SRT that will provide a good match of the “user specified MLSS concentration” with the “model calculated MLSS concentration.” Go back to the sheet tab entitled “**Input Output Data**” and change the SRT value(s) as needed and click the “**Analysis**” button again. Keep changing the SRT values as necessary to get a good match of the input (reported) MLSS and output (estimated) MLSS.

If the default values for the biokinetic constants (in red) are changed by the user, the model will process the new values and provide the corresponding output data. If the user specifies a biokinetic constant value that is outside the recommended range, a message box similar to the following will appear:



The user should click the “**OK**” button, and the model will perform calculations with the atypical value specified by the user. **USING BIOKINETIC CONSTANTS OUTSIDE THE RECOMMENDED RANGE SHOULD BE DONE WITH CAUTION!**

The “**Revert to default**” button can be clicked if the user desires to go back to the biokinetic constant default values and to the SRT default values. The SRT default values are from 1 to 70 days. As noted above, the SRT values can be changed by the user. The default values for the biokinetic constants are as follows:

$f_d$	0.1
$Y$	0.6
$K_s$	60 mg/L
$k_d$	0.1 day <sup>-1</sup> at 20 °C
$k$	8 day <sup>-1</sup> at 20 °C

An example of the approximate operating conditions (based on the user specified input data) for the specified activated sludge process is illustrated on the next page. As described above, two output tables (one for “**Current Conditions**” and one for the “**Alternate Scenario**”) will be presented by the model. When running the model, these tables will be located under the “**Output**” heading on the **Input Output Data** sheet tab at the bottom of the page. Note that in the subsequent pages of this user manual, the revised Aerator Performance Data for the Alternate Scenario will also be presented.

**TSS sludge production (lb/day)** is the mass/day of suspended solids leaving the activated sludge process in the waste activated sludge; this is known as “intentional solids wastage.” **TSS in activated sludge effluent (lb/day)** is the mass/day of suspended solids leaving the activated sludge process in the effluent from the secondary clarifiers; this is known as “unintentional solids wastage.” The overall **total sludge production (lb/day)** is the sum of two values: the **TSS sludge production (lb/day)** and the **TSS in activated sludge effluent (lb/day)**. **Total sludge production (lb/day)** includes solids production due to heterotrophic biomass growth, cell debris accumulation, inert VSS in the influent, and inert inorganic TSS in the influent.

The **total oxygen requirements (lb/day)** include the oxygen required for carbonaceous BOD (CBOD) removal and the oxygen required for nitrogenous BOD (NBOD) removal. **Total oxygen req’d with denit. (lb/day)** is the **total oxygen requirements (lb/day)** minus the oxygen savings due to denitrification. For every pound of nitrate-N that is converted to nitrogen gas when operating in the denitrification mode, 2.86 pounds of oxygen are recovered or “saved.” As described in more detail below, the model assumes that denitrification efficiency is 70% (a very rough estimate). Thus, 70% of the nitrate-N created by nitrification will be converted to nitrogen gas in the model. **Total oxygen supplied (lb/day)** is determined by the type and horsepower of aeration equipment being used at the given operating conditions.

<b>Approximate Operating Conditions</b>	
Total average daily flow rate (mgd)	<b>2.85</b>
Aeration volume in service (mil gal)	<b>0.98</b>
Influent BOD5 concentration (mg/L)	<b>142</b>
Influent BOD5 mass loading (lb/day)	<b>3,375</b>
Sec ww Oxid N load (lb/day)	<b>594</b>
Sec ww TSS load (lb/day)	<b>5,087</b>
F/M ratio	<b>0.143</b>
Solids Retention Time (day)	<b>12.0</b>
MLSS (mg/L)	<b>3,845</b>
MLVSS (mg/L)	<b>2,884</b>
TSS Sludge Production (lb/day)	<b>2,500</b>
TSS in activated sludge effluent (lb/day)	<b>118.8</b>
Total Oxygen Requirements (lb/day)	<b>5,465</b>
Total Oxygen Req'd W/Denit. (lb/day)	<b>4,717</b>
Total oxygen supplied (lb/day)	<b>5,789</b>
Mixing intensity in the reactors (hp/mil gal)	<b>182</b>
RAS flow rate (mgd)	<b>2.01</b>
RAS recycle percentage (%)	<b>70.5</b>
WAS flow rate (mgd)	<b>0.032</b>
RAS TSS concentration (mg/L)	<b>9,300</b>
Total sludge production (lb/day)	<b>2,619</b>
Reactor Detention Time (hr)	<b>8.3</b>
VOLR (lb BOD5/(thou cu ft-day))	<b>25.76</b>
Effluent CBOD5 (mg/L)	<b>4.4</b>
Effluent TSS (mg/L)	<b>5.0</b>
Effluent Ammonia-N (mg/L)	<b>1.63</b>
Effluent NO3-N (mg/L)	<b>15.7</b>
Effluent NO3-N W/denit (mg/L)	<b>4.7</b>



The other output data noted above are self-explanatory in most cases. For an activated sludge process achieving some degree of *nitrification*, estimates of the effluent ammonia-N concentration and effluent nitrate-N concentration are provided. If the activated sludge process is operated to achieve *denitrification* by incorporating an anoxic zone or by turning the aeration equipment off for a few hours each day, a very rough estimate of the effluent nitrate-N concentration with *denitrification* is provided at the very end of the respective output table. The rough estimate of the efficiency of *denitrification* is 70%. Thus, the last value in the above table is 30% of the effluent nitrate-N concentration given in the next to last row of the table. Obviously, this is not a detailed simulation of *denitrification* efficiency but a very rough and conservative estimate that is helpful for assessing both the nitrogen load imposed on the receiving stream and the status of potential NPDES permit compliance.

In addition to the “**Output**” tables on the **Input Output Data** sheet tab, the model provides detailed output for each SRT value specified in the input data. The detailed output data for each SRT are provided in the **Calculations Current** sheet tab and the **Calculations Alternate** sheet tab at the bottom of the page. Moreover, the **Charts** sheet tab at the bottom of the page provides six graphs for each of the two input data sets (**Current Conditions** and **Alternate Scenario**). These graphs may be useful to the model user to view the impacts of SRT values on effluent soluble CBOD<sub>5</sub> concentration (S<sub>e</sub>), MLVSS concentration, MLSS concentration, sludge production as VSS (lb/day), sludge production as TSS (lb/day), and total oxygen requirements (lb/day) for the activated sludge process being modeled.

It should be noted that the effluent soluble CBOD<sub>5</sub> concentration (S<sub>e</sub>) is calculated by the following equation:

$$S_e = \frac{K_s(1+k_e\theta_c)}{\theta_c(\mu_{\max} - k_e) - 1}$$

where:

S<sub>e</sub> = effluent soluble CBOD<sub>5</sub> concentration, mg/L

K<sub>s</sub> = half saturation constant, mg/L

k<sub>e</sub> = k<sub>d</sub> = endogenous decay coefficient, day<sup>-1</sup>

Θ<sub>c</sub> = solids retention time, days

μ<sub>max</sub> = Yk, day<sup>-1</sup>

Y = biomass yield constant

k = maximum specific substrate utilization rate, day<sup>-1</sup>

An example of the **Actual Aerator Performance** output data for *existing conditions* (see page 9 for aerator input data for these *existing conditions*) is provided below.

Actual Aerator Performance	
Field OTR ( lb O2 / hp-hr)	<b>1.35</b>
Aerator energy use (kWh/month)	<b>83,538</b>
Energy cost (\$/month)	<b>4,595</b>

The **Field OTR (lb O2 / hp-hr)** is the actual oxygen transfer rate of the specified aeration equipment for the existing operating conditions. In this example, the **Field OTR** is low because the operating DO concentration is 3.5 mg/L for existing conditions. As discussed above, the aerator efficiency is 24% lower than if the operating DO concentration was 2.0 mg/L.

The total **aerator energy use (kWh/month)** is almost 84,000 kWh/month for the example input data at *existing conditions*. The **energy cost (\$/month)** for the example input data at *existing conditions* is about \$4600/month.

The input data for the aeration equipment used in this example for the *alternate scenario* are shown below.

Aerator Performance Data	
Operating DO concentration (mg/L)	<b>2</b>
alpha	<b>0.84</b>
beta	<b>0.92</b>
SOTR, lb O2 / hp-hr	<b>3.1</b>
Temperature (°C)	<b>20</b>
Aeration (hp) being operated	<b>255</b>
Elevation (ft)	<b>400</b>
Aerators operating time (hr/day)	<b>20</b>
Type of aerators (1, 2, or 3)	<b>2</b>
Speed of aerators (%)	<b>55</b>
Energy cost unit (\$/kWh)	<b>0.055</b>

An example of the **Actual Aerator Performance** output data for the given *alternate scenario* is provided below.

Actual Aerator Performance	
Field OTR ( lb O2 / hp-hr)	<b>1.78</b>
Aerator energy use (kWh/month)	<b>54,698</b>
Energy cost (\$/month)	<b>3,008</b>
Cost savings vs. current conditions (\$/month)	<b>1,586</b>

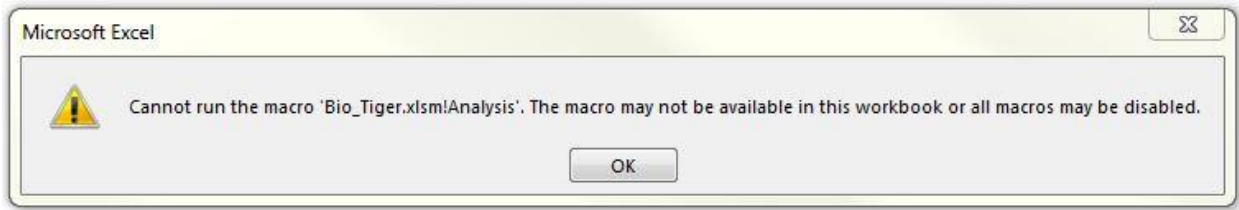
For this example and the *alternate scenario*, the **field OTR** is 1.78 lb/(hp-hr). The increase in aeration efficiency is due to the operating DO concentration of 2.0 mg/L for the *alternate scenario*. The model output for the revised Approximate Operating Conditions for the alternate scenario is presented below:

If one examines the revised **total oxygen supplied** for the *alternate scenario*, the total oxygen supplied is now 4,986 lb/day, which is significantly (about 800 lb/day) less than for *current conditions*. The reduction in oxygen supplied occurs because the blower only runs 20 hours per day and at only 55% speed for the *alternate scenario*. Looking at further efficiency improvements, with the blower turned off 4 hours per day to achieve denitrification, the **total oxygen req'd with denit. (lb/day)** is only about 4,700 lb/day (an overall reduction in oxygen supplied of 19% or about 1,100 lb/day).

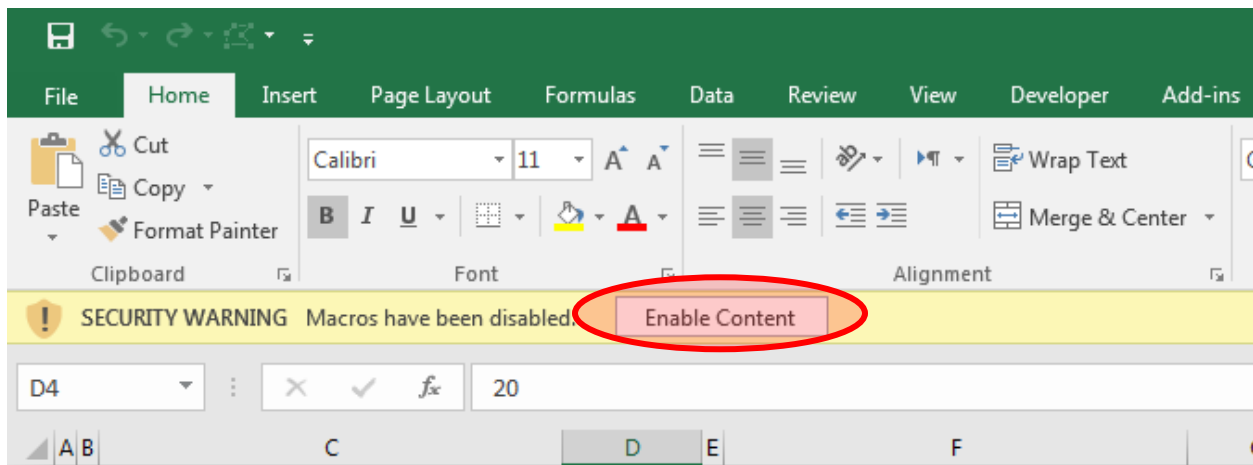
**Aerator energy use (kWh/month)** for the *alternate scenario* is about 54,700 kWh/month, 35% less than the energy used for *existing conditions*. The **energy cost (\$/month)** for the example input data for the *alternate scenario* is about \$3000/month. The **cost savings versus current conditions** is approximately \$1600 per month.

## V. Troubleshooting

If the following error appears, it means that macro actions are disabled in your Excel files. Since the Bio-Tiger model is developed in Visual Basic for Applications (VBA), it requires macro actions in the Excel file to be enabled.



If you see the yellow ribbon, click “Enable Content”. This will enable macros in your Excel file. If you cannot see the yellow ribbon, do the following procedures:



- Click the File button, and then click Options.
- Click Trust Center, click Trust Center Settings, and then click Macro Settings.
- Click one of the options below:
  - Disable all macros with notification
  - Disable all macros except digitally signed macros
- Click OK, close the Excel file and save the settings.
- Reopen the Excel file. Now, you should be able to see the yellow ribbon. Click “Enable Content.”



Info

New

Open

Save

Save As

Save as Adobe  
PDF

Print

Share

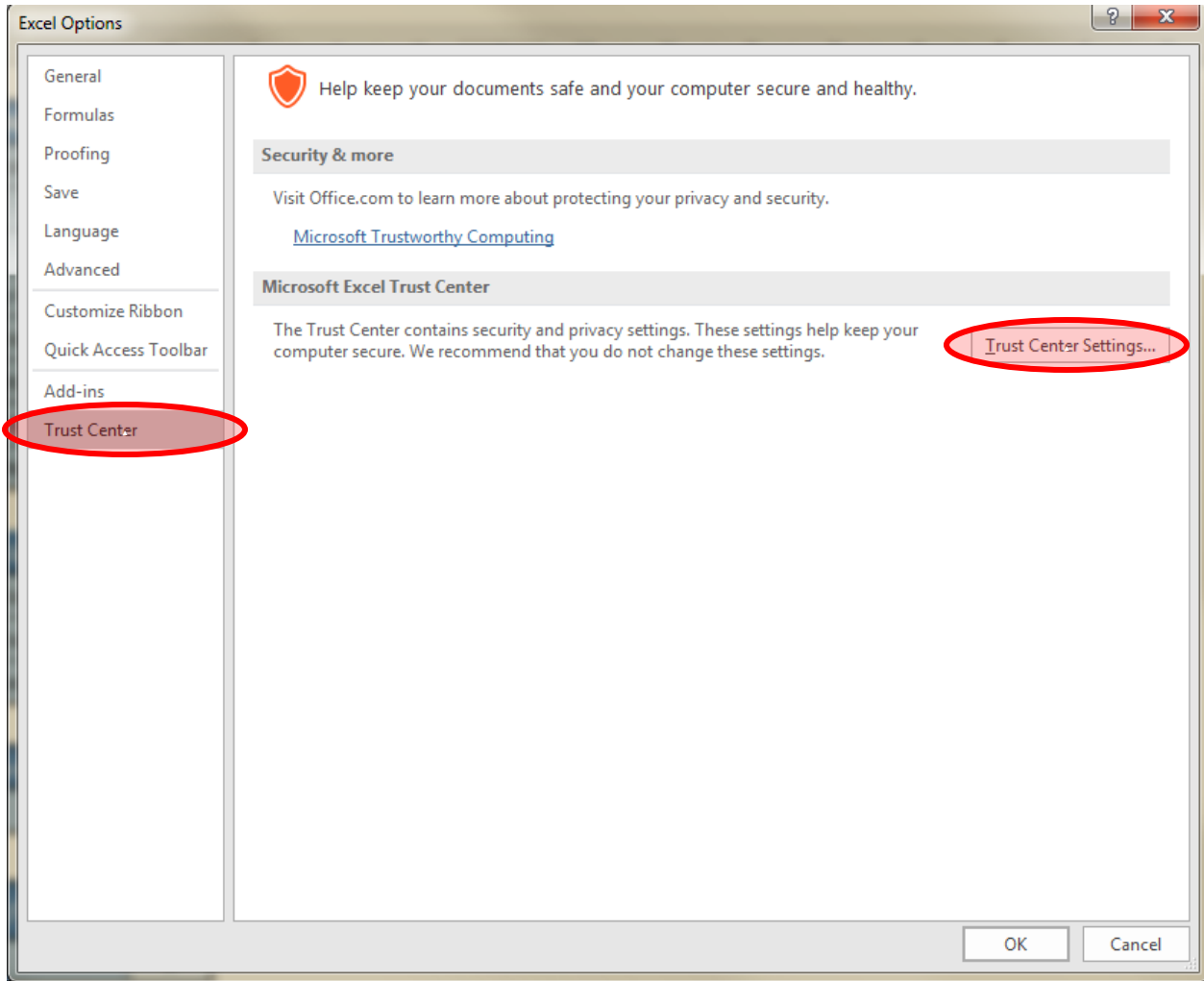
Export

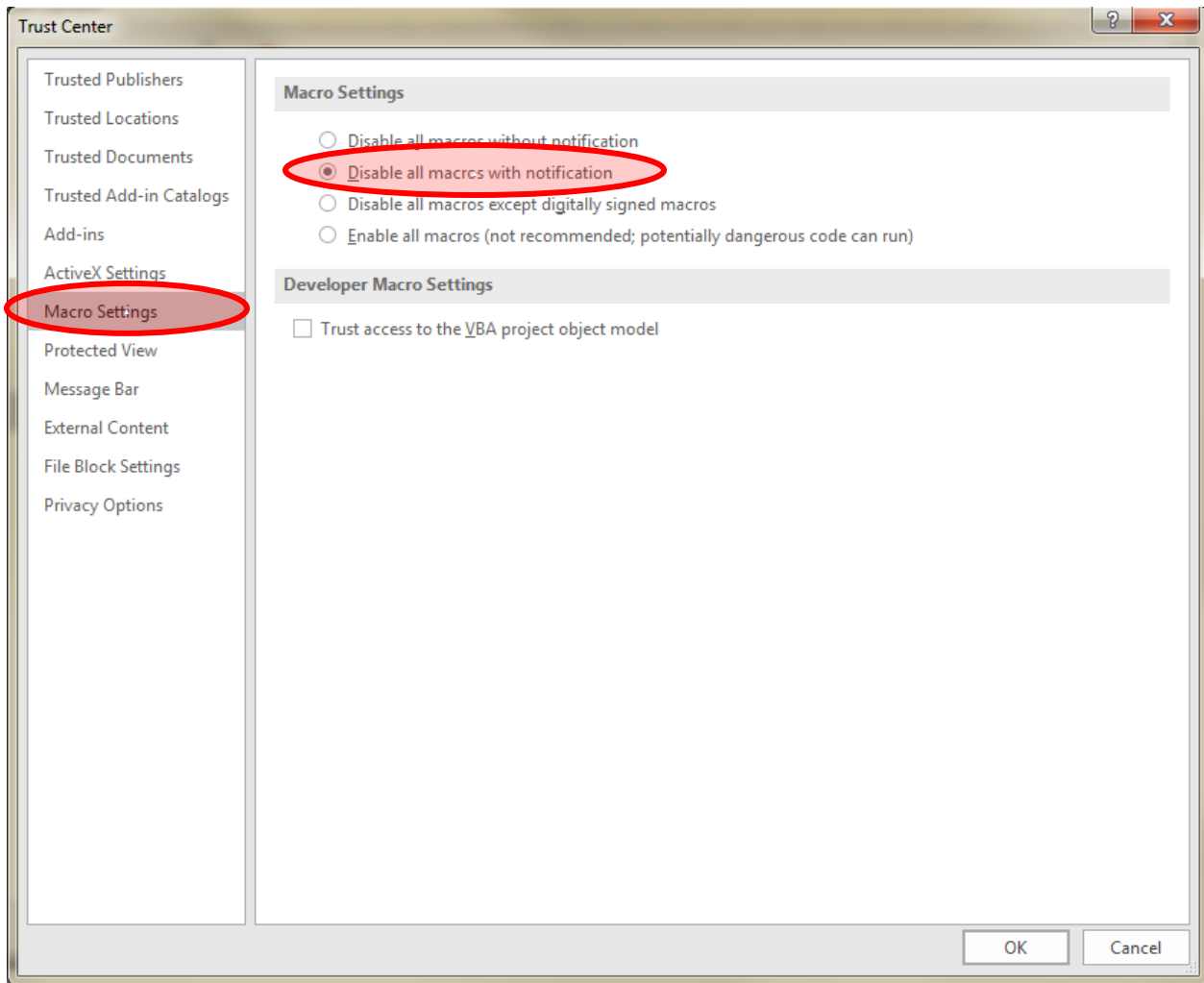
Close

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Account

Options





If the following error appears, it means that some of the cells in the input tables are empty or the value is zero. Please fill all the cells with reasonable values to correct this error.

