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Bio-Tiger Model User Manual

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

**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).

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1. **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 biological demands 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

Because changes in the operational strategy for an activated sludge process could have significant impacts on plant performance and effluent quality, it may be advisable to seek input from the city’s engineer. While the model provides very good information about activated sludge process performance when alternate operating strategies are being considered, having input from the city’s engineer prior to implementing process changes should be very valuable. Moreover, it may be useful to alert appropriate state regulatory agency personnel prior to making changes to process operations; their input should also be very valuable.

In most cases, it is best to use data based on at least 12 months of the specific activated sludge process historical information and biokinetic constant values suggested by Metcalf & Eddy and/or by Dr. Moore. If operational conditions vary significantly between seasons (because of tourism, academic schedules, operator discretion, etc.) to the extent that using annual averages is not practical, 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. When the user uses other values, 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 industrial wastewater, it may be desirable to use values outside the recommended ranges. The user just needs to be very careful in selecting the appropriate biokinetic constant values.

The Bio-Tiger Model is based on biokinetic equations that are given in the book, Wastewater Engineering Treatment and Reuse (4th 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 (BOD5) 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 he or she provides accurate data 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.

1. **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** |
| So (mg/L) | **142** |
| V (mil gal) | **0.98** |
| 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** |
| **fd** | **0.1** |
| **Y** | **0.6** |
| **Ks (mg/L)** | **60** |
| **kd at 20°C (1/day)** | **0.1** |
| **k at 20°C (1/day)** | **8** |

***Temperature*** is obviously very important because temperature impacts the rate of microbial reactions. The biokinetic constants, kd 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 “kd” 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 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 “So”*** is the concentration of CBOD5 *that enters the activated sludge reactor*. In other words, the growth limiting substrate in the Bio-Tiger model is CBOD5. Defining “So” accurately is absolutely critical in terms of producing model results in which the user can have good confidence. Obviously, the influent CBOD5 concentration changes during the day and throughout the week. Thus, the input value should represent the “average” CBOD5 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 non-biodegradable volatile suspended solids in the activated sludge influent. 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 mineralized 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 (nitrite lock) can occur under some 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, Dr. Moore has used this approach with reasonably good success for many years.

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 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 model user. However, it is essential that reasonable values be selected for any model simulation. The suggested guidelines are noted below:

Influent TSS concentration, mg/L Inert VSS, mg/L Inert Inorg. TSS, mg/L

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” CBOD5 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 CBOD5 will decrease with increasing SRT for the same effluent TSS concentration. The total CBOD5 of the effluent is the “chunky” effluent CBOD5 plus the soluble effluent CBOD5.

***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. Although MLSS concentration may be slightly different in the reactors (if more than one reactor is in use) used in the process, it is best to select an “average” MLSS concentration for the reactors.

***The term “fd”*** is the fraction of biomass that remains as cell debris. The typical range for “fd” 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 BOD5 consumed. The “net” yield of biomass depends on kd and SRT; the net yield decreases as kd increases and as SRT increases.

***The term “Ks”*** is the half saturation constant. The typical range for this parameter is 25 to 100 mg/L. It impacts substrate (BOD5) utilization and biomass growth.

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

1. **Bio-Tiger Model Aerator Performance Input Data**

The model gives the user the opportunity to evaluate the performance of aeration equipment 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 O2 / 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, 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). 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 (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.

**Field OTR** [lb/(hp-hr)] = **SOTR** x {[(βρCs) - C] x (α x 1.024(T-20))}

9.17

where:

Cs = saturation oxygen level in clean water at the design altitude, mg/L

C = operating oxygen level in wastewater at the design altitude, mg/L

α = O2 transfer coefficient in wastewater/ O2 transfer coefficient in

clean water

β = Cs in wastewater/Cs in clean water

ρ = correction factor for Cs 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, Cs 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 model 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 Cs appropriately by adjusting the value of ρ.

**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, and so on. The typical range for **energy cost unit** is $0.05 to $0.15 per kWh.

1. **Executing the Model and 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 a message box that states “*The difference between the reported and estimated MLSS is more than 100 mg/L. Change the SRT values to have a better estimation*.” To do this, 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 will appear that states “*The value of the given constant is out of the typical range*.” 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:

fd 0.1

Y 0.6

Ks 60 mg/L

kd 0.1 day-1 at 20 °C

k 8 day-1 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. Two output tables (one for “**Current Conditions**” and one for the “**Alternate Scenario**”) are provided under the “**Output**” heading on the **Input Output Data** sheet tab at the bottom of the page.

**TSS sludge production (lb/day)** is the mass/day of suspended solids leaving the activated sludge process in the waste activated sludge; it 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; it is known as “unintentional solids wastage.” The **total sludge production (lb/day)** is the sum of **TSS sludge production (lb/day)** and **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, 2.86 pounds of oxygen are 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.

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

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.

In addition to the “**Output”** tables of 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 CBOD5 concentration (Se), 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.

It should be noted that the effluent soluble CBOD5 concentration (Se) is calculated by the following equation:



where:

Se = effluent soluble CBOD5 concentration, mg/L

Ks = half saturation constant, mg/L

ke = kd = endogenous decay coefficient, day-1

Ɵc = solids retention time, days

μmax = Yk, day-1

Y = biomass yield constant

k = maximum specific substrate utilization rate, day-1

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) | **1.35** |
| Aerator energy use (kWh/month) | **83,538** |
| Energy cost ($/month) | **4,595** |

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 for this example for the *alternate scenario* are shown below.

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

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) | **1.78** |
| Aerator energy use (kWh/month) | **54,698** |
| Energy cost ($/month) | **3,008** |
| Cost savings vs. current conditions ($/month) | **1,586** |

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*. If one examines the **total oxygen supplied** for the *alternate scenario*, the total oxygen supplied is now 4,986 lb/day, which is significantly 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*. With the blower turned off 4 hours per day to achieve denitrification, the **total oxygen req’d with denit. (lb/day)** is about 4,700 lb/day.

**Aerator energy use (kWh/month)** for the *alternate scenario* is about 54,700 kWh/month, 35% less than that 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.