WHAT DOES IT TAKE TO MODEL A WASTEWATER TREATMENT PLANT?

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ABSTRACT

Wastewater Treatment Plant modeling is a useful tool for performing plant capacity assessments and improving plant operations; therefore, saving energy and chemical costs. However, modeling is not an easy task for utilities. They may require help from experts in creating a model framework on which the utilities can build.

Modeling a WWTP involves several steps. It is an interactive process by nature. The first activity is determining the goals of the model. Usually, the complexity and level of model calibration depends on the purpose of the model. The second step is data collection where historical plant data and additional plant information is gathered through a sampling program and collected. The third step is data analysis which includes mass balances, data screening, and hand calculations. The fourth step is model setup and calibration which incorporates the analyzed data into the model. Once all the steps are complete, the modeler adjusts several model parameters to mimic plant operation. If another set of independent data becomes available, model verification is recommended. Finally, several model simulations can be run under different scenarios to better understand plant limitations or responses to operational changes.

This paper describes in detail all the steps required to model a WWTP. In addition, it discusses major challenges encountered when developing a model framework. It includes typical model simulations for a plant assessment analysis.

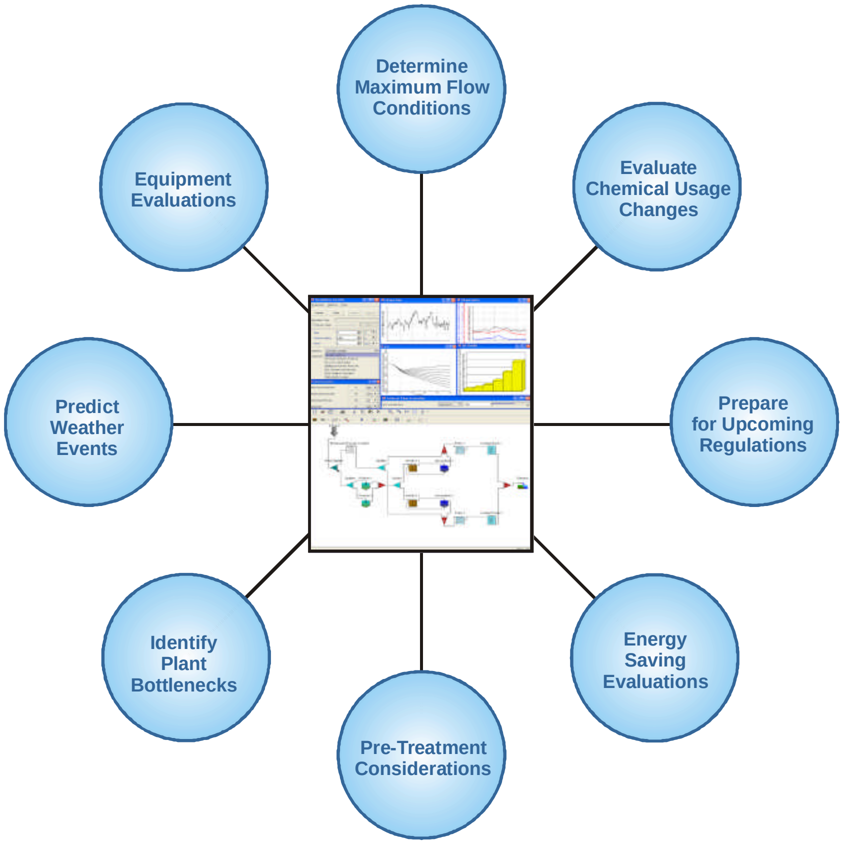
KEYWORDS

Modeling, wastewater, process optimization

INTRODUCTION

Modeling is powerful tool for optimizing wastewater processes. Modeling may prove to be the operator's best friend by allowing the operator to understand and optimize the process. Once implemented and calibrated, a model offers many advantages such as saving significant costs by predicting the outcome of operational changes, as well as by performing an energy cost analysis. Figure 1 shows model utilization benefits, including examples of how utilities may benefit from modeling their plants.

Figure 1 – Model Utilization Benefits



Wastewater treatment plant (WWTP) modeling is a useful tool for performing plant capacity assessments and improving plant operations; however, modeling is not an easy task for utilities. Although a lot of effort has been made to facilitate and promote the friendly usage of computer-based simulation tools by municipalities, modeling in practice requires a certain level of process expertise and model understanding. A great idea for utilities is to reach out for help from experts in creating a model framework on which the utilities can learn and build upon.

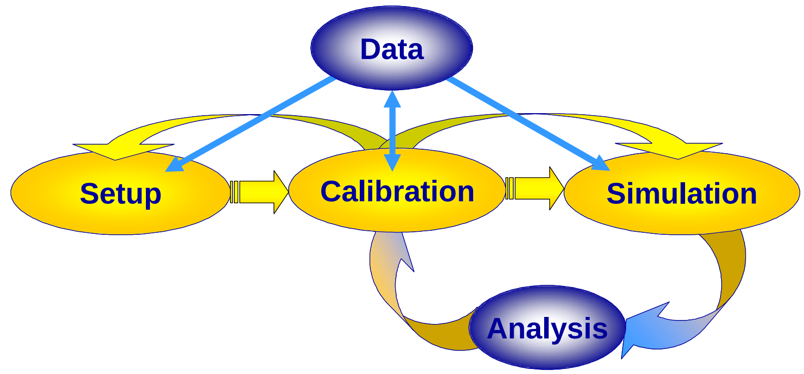
A model is a representation of a real system. Thus, the biggest challenge of model developers and model practitioners is to utilize model concepts and equations to represent the WWTP process dynamics. But wastewater treatment processes are complex and involve many reactions. Since Henze *et al*., (1987) published the first Activated Sludge Model Number 1 (ASM1), many improvements and additions have been made to ASM creating complex models that described 36 different processes. Therefore, the challenge for practitioners is to identify the critical process impacting the WWTP and make the best assumptions for estimating unknown plant data without compromising model accuracy.

This paper describes in detail typical steps required to model a WWTP. In addition, it discusses major challenges encountered when developing and implementing a model framework.

MODELING STEPS

Modeling is an interactive process by nature that involves several steps. Figure 2 present the typical model steps interrelations. The following paragraphs describe each step purpose, requirements, and challenges.

Figure 2 – Modeling Process



Determining Model Goals

The first activity for modeling a WWTP is determining the model purpose and scope. Although this activity seems an easy task, in reality is not easy. The major challenge encountered is understanding model capabilities and limitations. The recommended approach is to first brief the utility about the model capabilities and requirements in a simple but efficient language. Utilities are not usually interested in the mathematical expressions that represent the process unit but they are interested in how the model works and delivers the information. Once the staff is familiar with the specific software applicability, a brainstorm session is recommended to get ideas about modeling purpose. At this time it is useful to ask questions such as:

- How do you picture it working?
- What questions are you trying to answer? Examples: capacity assessment, retrofit, process operation change.
- Which unit processes are of interest?
- What are the most common problems encountered?
- Where are you spending more money?

When the modeler has several model purpose or goals ideas, it is recommended to prioritize them and select the most important and urgent. Many ideas could be interesting but costly; others could be less interesting but urgent. The complexity and level of model calibration and data required depends on the purpose of the model. Therefore, modelers recommend simplifying the model as much as possible and do not model the whole plant if it is not needed.

Data Collection

Data from the plant can be gathered by historical plant records and/or a sampling program. The minimum information required to run a model are the physical tank dimensions; piping and units interconnections; operational parameters such as RAS flow rates, WAS rates, MLSS, DO and air flows; and influent and sidestream flows and characterization. A useful tip for the modeler is to review the operator log for acknowledging the units and parameters monitored in a daily basis and the frequency and accuracy of those measurements.

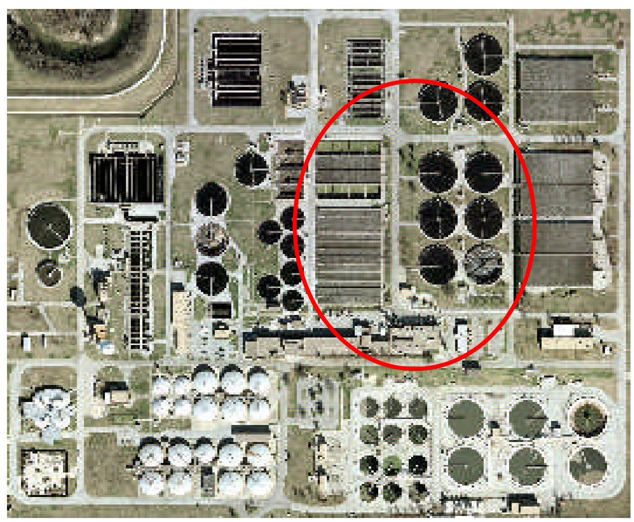
It is also recommended to review and get familiar with the utility database if they have one. But how much information should be collected? It depends; the plant stability and data reliability are the key factors that determine how much data is required.

A sampling program should be conducted during this step for collecting stream and process information that is not usually monitored on a daily basis such as the TSS, VSS, COD, fCOD, TKN, NO_X-N, TP and soluble P components of all streams. The sampling program usually lasts between one to two weeks and includes collection of 24-hour composite samples of major streams and 24- or 48-hour diurnal grab samples for assessing the nature of the diurnal variations of the loading patterns.

A sampling program is one of the most valuable engineer experiences because it provides the perfect opportunity to get to know the plant personnel and observe how the plant operates. The following bullets describe general recommendations for preparing and conducting a sampling program:

- Get a map (process diagram or site plan) and identify the locations and streams to be monitored.
- Acknowledge plant personnel and make sure everybody is on board and knows the purpose of the sampling exercise.
- Plan in advance and check with operators, staff, and engineers any anticipated plant performance variations.
- Be prepared and inquire about laboratory testing including labeled bottles for sampling.
- Take notes of all relevant occurrences or observations during the sampling program in regards to the collection of samples and plant operation.
- Be ready to work hard 24-hour a day for at least 1 week.

Figure 3 – Identification of Locations to Monitor during Sampling Program

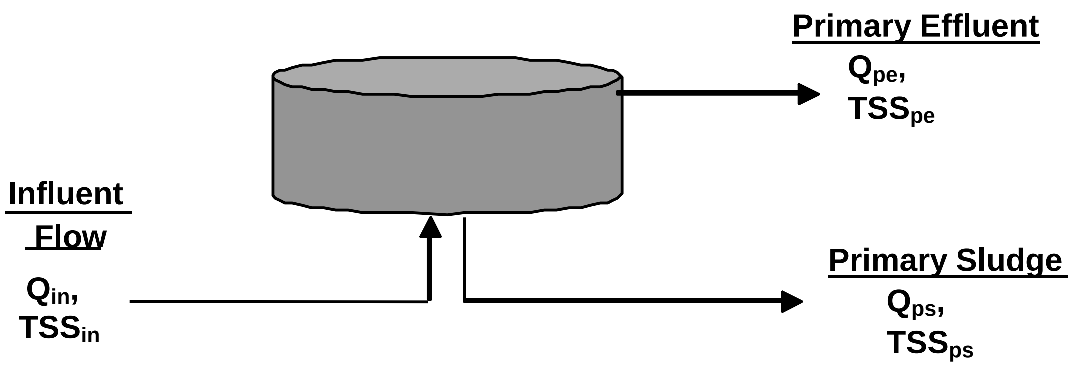


Data Analysis

This phase includes the study and thorough understanding of the WWTP by performing data screening, mass balances, and design hand calculations. Proper data screening early in the project is critical and will eliminate the old modeling adage “Garbage-In equals Garbage-Out”. The recommended tasks during this step are:

- Influent data check.
- Flows balance throughout unit processes.
- Data comparison between historical records and sampling program results.
- Solids mass balance around clarifiers.
- Loading assessments.
- Understand the plant sludge waste program and sludge age control to manage the solids.

Figure 4 – Solids Mass Balance around Clarifiers



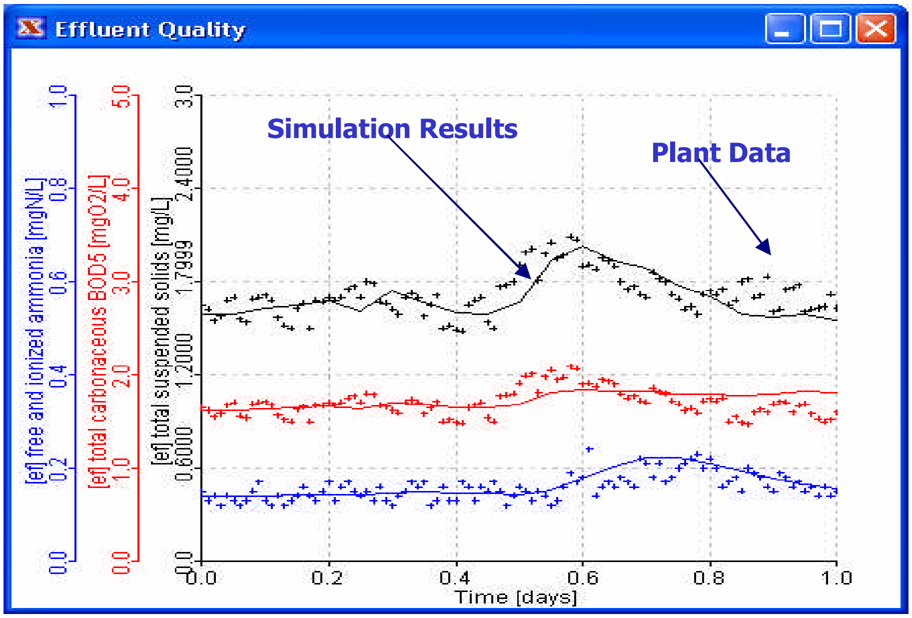
Model Setup and Calibration

A significant amount of time is typically invested during the model set up and calibration stages. Model setup includes the complete definition of each process unit in terms of physical, chemical, and operational parameters. Calibration consists of adjusting the model predictions until they match the selected set of data linked to the performance of the actual plant (see Figure 5). There are levels of calibration depending on the model purpose and data availability. The amount of data needed is directly proportional to the level of calibration desired. Typically, you will start with a general, initial, steady-state model calibration. A further detailed calibration can be performed later as more information is becomes available.

The modeler usually performs both model setup and calibration tasks at the same time, although some important decisions such as the type of library, the number of trains and environment setup are making in advance of model calibration. While performing calibration, a useful recommendation is to start from the back of the process train. This means to calibrate first the secondary clarifier and proceed upstream with aeration basins adding one process unit at a time.

Model calibration requires of the modeler's experience and ingenious to overcome challenges, establish the field of validity, and identify different errors associated with data and/or model limitations. Melcer, H. (2003) offers an excellent compilation of discussions about modeling in practice.

Figure 5 – Model Calibration



Model Verification

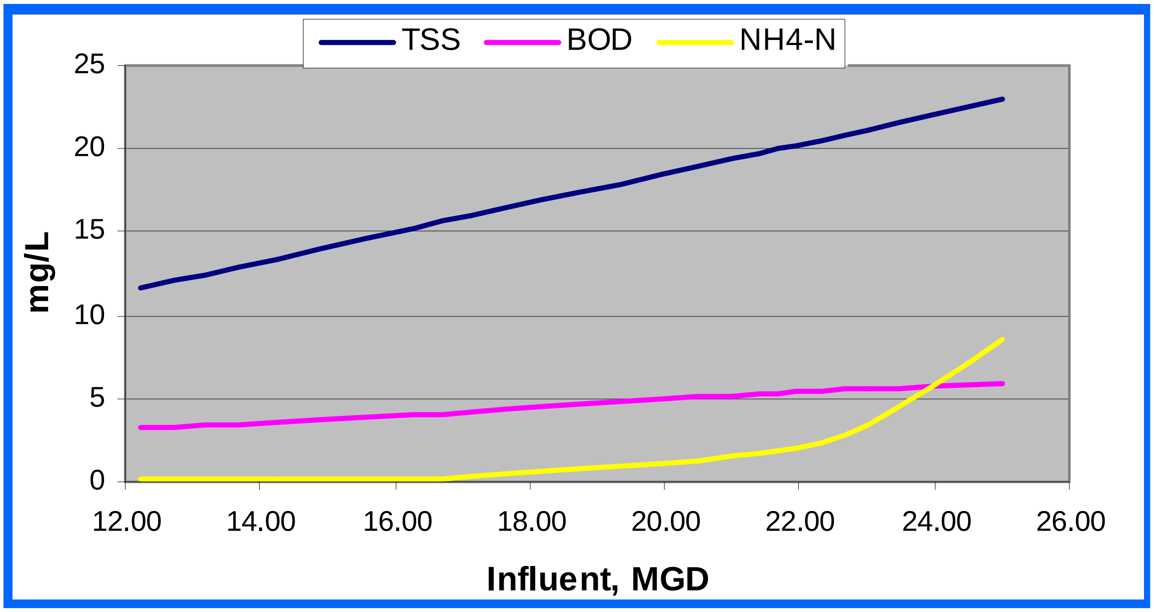
One step usually overlooked is model verification. Model verification consists of comparing the simulation results versus an independent set of data. Model verification allows corroborating the quality of calibration. Therefore, model verification is strongly recommended if another set of independent data is available.

Model Simulations

Once the model is calibrated, the modeler is ready to run model simulations. Simulation is an experiment performed on a model. Model simulations may include sensitivity analyses, “what if?” scenarios and process optimization tools. Model simulations are determined by the model goals and should include critical process variables. Model simulations are performed to better understand plant limitations or responses to operational changes. Some classical favorite model simulations are:

- Feasibility assessment: how much flow can get through? Figure 6 shows the simulation results of a typical feasibility assessment analysis.
- Loading conditions: how the diurnal loadings impact process performance?
- Aeration analysis: how much savings can be achieved by controlling DO?
- Solids management: how WAS and RAS flow rates impact the plant performance?
- Biological nutrient removal: which strategies should be implemented to achieved needed nitrogen and phosphorus limitations?

Figure 6 – Feasibility Assessment



CONCLUSIONS

Modeling is powerful tool for optimizing wastewater processes. Modeling may prove to be the operator's best friend by allowing the operator to understand and optimize the process. However, operator use of models requires experts to make models available to them. Modeling a real wastewater treatment plant is an iterative process that requires accomplishing several steps. Those steps include a great effort from the utilities and plant personnel to get a reliable set of data for model calibration. It is anticipated that by just executing the modeling exercise of collecting plant information and data screening offers invaluable understanding of the plant performance.

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