Process Control Systems at Water Resource Recovery Facilities:

Use of Process Simulation to Assist with Controller Design and Tuning

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ABSTRACT

WRRFs are inherently dynamic systems due to the influence of both external and internal disturbances. Disturbances cause plant performance to fluctuate and can result in plant upsets and violation of effluent discharge limits. Typical disturbances encountered in a WRRF include the following:

- Raw wastewater: flowrate, composition, concentration
- Pumping: flowrates
- Return sludge: flowrate, concentrations (COD, nitrate, phosphorus)
- Internal recycles: flowrate, concentrations (nitrate, DO)
- Supernatant return streams: flowrate, concentrations (nitrogen, phosphorus)
- Backwash: flowrate, DO
- Airflow: compressor disturbances
- Equipment failure
- Operator error

In WRRFs, process control systems are used to maintain key plant variables at or near their desired values (setpoints) and to allow the desired values to be selected to ensure safety and reliability, protect equipment, and reduce operating costs. Control systems reduce the variation in the key plant variables or control variables caused by disturbances by transferring this variability to manipulated variables

Different options are available for implementing process control within a WRRF. Process control may involve one or all of the following approaches:

- **Process design**: One of the most effective methods of control is to attenuate disturbances by incorporating appropriate plant design features. An example is the inclusion of equalization tanks to balance influent and return stream flow and concentration variations.
- **Fixed operating strategies.** These strategies typically involve using constant or proportional pumping rates and flow distributions (e.g. constant or proportional RAS and internal recycle flows, constant WAS flow, fixed step feed distribution). The settings used could be based on experience or taken from modeling studies.

- **Feedback control**. Feedback control systems use measured process output variables (controlled variables) to make automatic adjustments to process input variables (manipulated variables) using a control algorithm.
- **Model-based control**. Model-based systems use a process model to assist in the calculation of their control actions. This can range from simple model-based control calculations (e.g. waste rate calculated from SRT calculation based on average values), to feedforward/feedback control, to complex model-based feedback controllers.

Control systems can be manual, so that operators observe the plant and implement control actions manually, or automatic control loops employing feedback or model-based control. Automatic control systems typically consist of local control loops that are managed by a supervisory control and system data acquisition system (SCADA). Potential loops include:

- Influent flow rate and flow splits
- Primary sludge pumping rate
- Phosphorus control through metal salt addition
- DO control in aeration tanks
- Ammonia control through adjustment of DO controller set point
- SRT or MLSS control through adjustment of WAS flow rate
- MLSS control through step feed
- RAS flow control
- TN or NOx control through internal recycle adjustment and/or carbon addition
- Solids capture control in dewatering through adjustment of polymer addition

Integrated process, control, and equipment models are a useful tools to assist with control design and tuning at water resource recovery facilities (WRRFs). Simulation models serve as virtual WRRFs which can be used to design, tune, and test control systems. In addition, simulation models can be used as a basis for generating the models used in model-predictive control systems.

This paper illustrates using examples how process simulation can be used to design and test control systems for wet weather flow control, sequencing batch reactor (SBR) control, and blower and air distribution control in aeration systems. In wet weather control, simulation can be used to determine the impact of bypasses, storm tanks, and step feed strategies on maintaining sludge inventory and minimizing the impact to the receiving water bodies. For the case of SBRs, a Petri-Net discrete-event controller is simulated that shows the potential energy savings associated with ammonia-based control during the aerated phase. A comparison of pressure-based and flow-based control of aeration blowers is presented. Finally, an aeration system control example is presented that demonstrates the impact of temperature on control system performance and highlights that the optimal diffuser distribution in a plug-flow aeration basin depends on the temperature and loading conditions.

ABOUT THE AUTHORS

Oliver Schraa is the CTO at inCTRL Solutions, and has over 20 years of experience in WWTP design and costing, process modeling and simulation, optimization, and process control. He is the chair of the WEF Biofilm Interest Group, vice-chair of the WEF I&C Workgroup, vice-chair of the WEFTEC conference facility operations symposia, a member of the WEF Modeling Expert Group, and an expert member of the IWA Design and Operations Uncertainty Task Group. Oliver contributed to the following WEF publications: Operation of Municipal Wastewater Treatment Plants – MOP 11, Wastewater Treatment Process Modeling – MOP No. 31, Nutrient Removal - MOP No. 34, and Solids Process Design and Management. *Contact: schraa@inctrl.ca*

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The Authors are the Vice-Chair and Chair of the WEF MRRDC I&C Workgroup. This presentation will consist of information provided by multiple members of the workgroup and will be peer reviewed by independent professionals from WEF's related committees.