Determining and Assessing Corrective Action Strategies for Treatment Plants Exposed to Chemical Toxins

WERF, in partnership with the U.S. Environmental Protection Agency (U.S. EPA), identified a need to develop proactive corrective action strategies that minimize the impact of chemical, biological, and radiological (CBR) contaminants on wastewater treatment plants (WWTPs). These CBR spills can result from 1) accidental or intentional introduction of toxins into the collection system, 2) upstream decontamination event, or 3) a natural disaster.

This project provides valuable information to enable a plant to develop a support system that will help it reduce or potentially eliminate the impact that a suspected toxic compound has on the facility and is a follow-up to Feasibility Testing of Support Systems to Prevent Upsets (project no. 03CTS7S) which provides a great deal of background information on Decision Support Systems (DSS), including a comprehensive review of software and data analysis techniques that have been used by various industries to detect upsets.

The wastewater treatment industry lacks a systematic corrective action framework aimed at mitigating the impact of process-upset events resulting from direct or indirect introduction of contaminants into collection systems. This report presents the development and testing of corrective action strategies for two different wastewater treatment plants exposed to two toxins and a first generation decision support system framework that can be developed into a tool that guides the actions of operators during upset events.

The goal of this project was to develop and demonstrate detailed response protocols for a subset of shocked biological treatment processes, and to integrate the experience gained from experiments into a first generation decision support system that can assist operators during upset events. Its primary objectives include:

- Develop WWTP-specific corrective action strategies to mitigate toxic shock events.
- Experimentally evaluate the effectiveness of the developed corrective action strategies through laboratory- and pilot-scale shock event simulations.
- Develop a first generation DSS framework that can be used by others to further develop detailed, site-specific DSS plans that will guide operators during chemical shock events.

Experimental investigations were conducted on laboratory and pilot-scale set-ups for a continuous complete mixed nitrifying activated sludge system and a 5-stage Bardenpho system with nitrogen and phosphorus removal. WWTP-specific corrective actions were developed by an expert panel prior to the experimental phase. The developed corrective actions were tested through laboratory- and pilot-scale experiments for each toxin.

Research Results

Two toxins were selected as priority toxins based on an EPA-approved contaminant prioritization framework developed during the WERF 03CTS2S project. This report presents detailed evaluations of the effectiveness of WWTP-specific corrective action strategies for the mitigation of toxic chemical shock events. Additionally, this report introduces a contaminant- and WWTP-specific DSS that can be further developed to aid operators in enacting rapid remedial intervention efforts when confronted by similar upset event scenarios.
Results indicate the presence of primary clarifier upstream of the biological processes provides a sufficient hydraulic buffer in order to facilitate complete dissipation of a hypochlorite pulse shock, and therefore does not require any remedial intervention. Under a worst-case scenario, the implementation of corrective actions for the cadmium stress resulted in greater process deterioration for treatment trains subjected to remedial intervention. However, the corrective action strategies may allow for reduced impact on the effluent quality and faster recovery under normal operating conditions.

**Decision Support System Framework**

The research also presents a decision support system framework that provides systematic guidelines for short-term and long-term operator actions that can be initiated during an upset event. The framework can serve as a starting point for utilities to develop WWTP-specific response plans that deal with upset events.

Using information from previous reports on developing decision support systems, steps were identified and used to create a DSS framework for applying corrective actions to address treatment process upset, which include important feedback loops designed to enhance the predictive power of the DSS over time.

The objectives of the DSS are to provide operators with a systematic decision-making process to respond to a range of contamination events that will minimize the degree to which damage is imparted to the treatment process and environment, while ensuring the utility’s ability to meet its obligations to regulators. The DSS framework needs to be sufficiently flexible so that it can be implemented at and calibrated for different utilities. This objective was developed as an outcome of a workshop conducted with utility personnel, treatment process operations specialists, design engineers, and the research team. The objective recognizes that corrective actions that are designed for one utility are likely to be quite different from other utilities, as the parameters that constrain the decision (i.e., availability of extra storage capacity, the sensitivity of the environment being discharged to, weather conditions, etc.) are heavily site-specific.

The experience with the experimental phase of this project highlights the need for corrective action practices to be validated, either through further experimentation or modeling, in order to enhance the power of the DSS. Therefore, an important element of the framework presented here allows for corrective action strategies to be refined through experience. The framework does not explicitly incorporate uncertainty analysis, although uncertainty analysis would be an important element of any automated DSS developed. Having such an element integrated with a DSS will allow operators to understand the risk associated with each decision they face, and creates the possibility that decisions formulated from the prescriptive, data-driven DSS can also be influenced by locally relevant values. This aspect of DSS development reflects the personalized/local nature of DSS refinement that must occur for each utility that implements such a system.