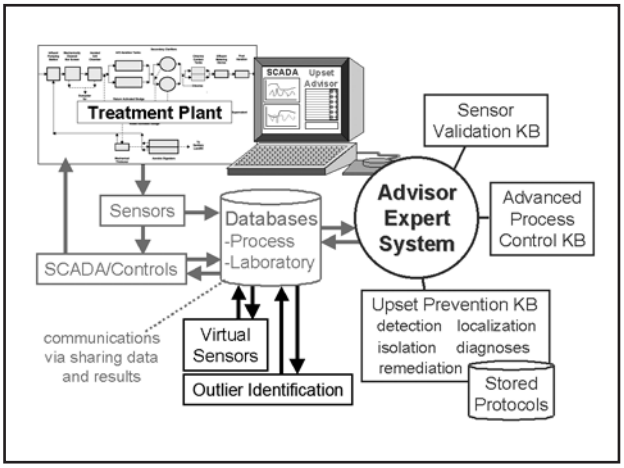
Feasibility Testing of Support Systems to Prevent Upsets

This is one of the 12 security projects initiated by the Water Environment Research Foundation under a U.S. EPA-funded security grant provided in the aftermath of 9/11. The overarching objective of this body of research is to protect public health and the nation's wastewater infrastructure from multiple hazards (natural and human-induced disasters).



Main elements of an advisory expert DSS for wastewater treatment plant operations.

WERF and U.S. EPA have elucidated a clear need for a security framework for upset detection, prevention and/or mitigation in the wastewater treatment industry as part of an emergency response plan. This need is further highlighted by an earlier WERF project, *A Review and Needs Survey of Upset Early Warning Devices* (99WWF2), which reports that 64% of 101 surveyed plants have experienced process upsets. Security systems for upset prevention should focus on monitoring devices upstream from the biological wastewater treatment plants for greatest effectiveness.

Determining the Feasibility of Support Systems

The goal of this decision support system (DSS) project was to determine the feasibility of support systems to prevent upsets caused by chemical/biological/radioactive contaminants (C/B/R) introduced upstream of the wastewater treatment plant (WWTP). Decision support systems are an amalgamation of functions such as monitoring, anomaly detection, machine learning, situational awareness, and remediation.

The research team developed and tested a DSS prototype for the prediction of contamination events at WWTPs. They reviewed available technologies and, using examples of DSS software, provided guidance in the development of a DSS module.

The research team reviewed upset event support systems and anomaly detection technologies used for industrial and computer network security. Real-time information collected by conventional sensors/analyzers (measuring pH, conductivity, temperature, alkalinity, dissolved oxygen, etc.) was subjected to advanced data mining techniques to predict the experimentally simulated toxic shock. (The DSS prototype uses an outlier identification methodology to predict a contamination event.) This anomaly detection approach will aid WWTP operators in executing remedial actions following the detection of an upset event.

The report also describes the experimental testing of the DSS on data collected by online sensors and analyzers specific to the wastewater industry.

BENEFITS

- Reviews state-of-the-art upset event support systems and anomaly detection technologies in various industries, and assesses their applicability for the wastewater industry.
- Develops an expert decision support system (DSS) prototype to aid operators in executing remedial actions following the detection of an upset event.
- Discusses sensor installation and operating practices to ensure compatibility with DSS modules.
- Discusses validation of sensor signal integrity and site-specific DSS module calibration prior to use.

RELATED PRODUCTS

A Review and Needs Survey of Upset Early Warning Devices (99WWF2)

Identify, Screen, and Treat Contaminants to Ensure Wastewater Security (03CTS2S)

Emergency Response Plan Guidance for Wastewater Systems (03CTS4S)

Strategy, Guidance, and Decision Support Systems for Deployment and Development of Upset Early Warning Sensor Systems for Wastewater Collection and Treatment Operations (04CTS9S)

Integrated GIS-Based Consequence Assessment Model for Sewer and Stormwater (SewerNet) (04CTS10S)

RELATED ONGOING RESEARCH

Detailed Protocols for Treatment Process, Standard Response, and Collection System Disruptions (04CTS11S)

AVAILABLE FORMAT

Online PDF posted on www.WaterISAC.org.

Refer to: **STOCK NO. 03CTS7S**

For more information, log on to **www.werf.org**.

DSS Project Identified Problems with Data Quality

The project approach utilized multivariate state space reconstruction (MSSR), determination of optimal sampling frequency, signal decomposition, signal validation, clustering, classification, and finally outlier identification using nearest neighbor classification, convex hulls, and spectral pattern perturbations.

Key Project Tasks

1. Establishing Project Baseline
2. Software Assessment
3. Development of a DSS Based on Historical Data
4. Development of a Prototype DSS Based on Online Instrumentation
5. Application of Framework to Utilities

The researchers developed a DSS in conjunction with data collected from a pilot-scale study conducted at the Plum Island WWTP, in Charleston, SC; and historical data provided by the Long Creek WWTP, in Gastonia, NC, and the Commonwealth Science and Industry Research Organization (CSIRO) in Australia. The pilot-scale study at the Plum Island WWTP simulated contamination events involving salt (NaCl), sodium hydroxide (NaOH), cadmium, octanol, chloro-2,4-dinitrobenzene (CDNB), and 2,4-dinitrophenol (DNP). Conventional as well as advanced sensors, such as ChemScan and Stiptox, were used for data collection.

Problems with data quality and the subsequent use of raw data highlight the need for using the best sensor installation and operating practices in WWTPs. Of the data obtained by the conventional sensors used in this study, the data collected from turbidity sensors were greatly affected by low signal to noise ratio, whereas the temperature measurements were unresponsive to shock events. Data from the conductivity, ORP, and pH sensors proved useful in predicting simulated shock events. However, the probes required extensive manual cleaning around the shock events and generated poor quality data for the field study, which highlights the need for validating the integrity of sensor signals before use and calibration of DSS modules for site-specificity.

Key Issues for Development of Future DSS

Despite data quality problems, the project presented a solid approach to applying DSS systems to sense, detect, and mitigate upset events – using conventional sensors and data mining techniques in wastewater treatment plants. This type of approach has much to offer towards the development of future robust DSS for WWTPs.

The research team identified some key issues for a WWTP DSS:

- Automated real-time data analysis is attractive; however, it will require the filtering of bad data. The DSS should be able to differentiate between real upset events and bad data resulting from probe/sensor malfunction. Good discrimination between false positives and real events will provide the confidence level essential for the incorporation of automated alarm systems.
- The DSS should be able to collect and store large amounts of data with provisions for easy access by human users. Anomaly detection, unlike pattern recognition, involves handling large amounts of information.
- Though automation provides an enhancement to technology, the user must retain the ability to access and modify critical components and be the ultimate decision maker.

It is important to note that another WERF security project under the U.S. EPA grant, *Detailed Protocols for Treatment Process, Standard Response, and Collection System Disruptions* (04CTS11S), is already benefiting from this project.

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