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Automation of disinfection process using ORP reduces chlorine by 32%

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Operator accesses the control system at the Sudbury Wastewater Treatment Plant (below).

The City of Greater Sudbury, with a population of 155,000, is located 390 kilometres north of Toronto. At 3,627 square kilometres including water bodies, it is the largest municipality in Ontario. The main Sudbury Wastewater Treatment Plant is an 80,000 m^3/day high rate activated sludge facility, serving a community of over 85,000 residents and over 4,600 local businesses. A future plant expansion will see the plant capacity increase to 102,375 m^3/day.

Chlorination is the final stage of the treatment train before the effluent is discharged into Junction Creek, which is immediately upstream of Kelly Lake. In order to achieve an E-Coli discharge limit set in the facility's Certificate of Approval, year-round chlorination is required. Manual control of chlorine feed to the contact chamber produced good results with respect to E-Coli discharge compliance.

However, it was hypothesized that chlorine was being overfed to ensure compliance since the manual chlorine feed adjustments could not keep up with the frequent changes in demand associated with a municipal wastewater treatment plant. The City Plants Engineer and staff at the Sudbury facility decided to investigate methods to automate chlorine feed to the contact chamber to get better control of the disinfection process.

Using a gas chlorinator, chlorine gas is fed from tonne cylinders into a wetwell directly upstream of the contact chamber. Two 2150 m^3 contact chambers provide an average and minimum detention time of 60 and 15 minutes, respectively. In order to ensure disinfection to the required level, historic measurements have shown that maintaining a total chlorine residual between 0.5 and 1.0 mg/L at the outlet of the contact chamber, prior to discharge to Kelly Lake was adequate.

Effluent samples were taken three times per week for total chlorine analysis. Depending on the results measured, the output from the chlorinator was either increased, or decreased, to bring the chlorine residual number to within the acceptable range. Since manual adjustments were only performed a few times per week, adjustments were not able to account for changes in oxidant demand that continually occured throughout the day. In order to ensure proper disinfection during peak demand, chlorine was overfed. This resulted in proper disinfection but high chlorine residuals discharging into the receiving water body during periods of low demand.

Flow Pacing

The first attempt to automate the chlorination process was with flow pacing. A 4-20 mA signal from the plant flow meter was used to pace the output from the gas chlorinator to the effluent flow through the contact chamber. It was quickly determined that automatic chlorination control by flow pacing was inadequate and often resulted in chlorine overfeed and underfeed. Although hydraulic loads can increase significantly, coliform levels do not increase proportionately. Conversely, low plant flows do not necessarily reflect low coliform levels.

Amperometric Chlorine Analyzer

An amperometric analyzer was installed to automatically measure the total chlorine residual in the effluent exiting the contact chamber and adjust the chlorinator output to maintain a residual setpoint. Operators found that the sensing electrode fouled very quickly, which resulted in inaccurate residual readings, and required frequent cleaning. Furthermore, the analyzers required a steady supply of reagents to function properly and were dependent on proper calibration procedures being followed. Operators at the Sudbury facility found that the amperometric analyzer was too maintenance intensive to automate their disinfection process.

Research also indicated that chlorine residual measurement is not a good predictor of disinfection. Measuring residual only tells how much chlorine is left at a given point in time. Chlorine residual is not a measure of the work value of the chlorine or a measure of the chlorine demand, which is continually changing. Controlling with residual measurement can, therefore, result in variable E-Coli levels discharging to the environment.

High Resolution Redox (HRR)

Research by Danish virologist Dr. Ebba Lund ("*Oxidation Inactivation of Poliovirus*", Copenhagen, 1963) indicated a direct link between the disinfection rate of poliovirus and the oxidation reduction potential (ORP). She found that a given ORP held for a period of time would produce a repeatable inactivation curve. Lund’s work led to the development of Lund’s Law of Oxidative Disinfection: The log decrease in microorganism activity is proportional to the ORP maintained, times the contact time.

Plant management decided to investigate the use of ORP as the control basis for the disinfection process. ORP (also referred to as redox) is a measurement of the electromotive force (emf) generated when an oxidant is present in an aqueous solution. Measurable in millivolts (mV), the strength of this force is directly proportional to the oxidative strength of the treated system. The higher the concentration of the oxidant, the higher the voltage. Conversely, the higher the concentration of the reductant (i.e. E-Coli, organic material, etc.), the lower the voltage. A redox sensing instrument, which detects this voltage, can be used to monitor the chlorine demand. The ORP of the Sudbury WWTP’s effluent, at any given time, is a direct measurement of the current oxidant demand of the system.

A Strantrol® Model 890 High Resolution Redox (HRR) controller, manufactured by USFilter/Stranco from Bradley, Illinois, was installed by Indachem Inc. at the Sudbury WWTP as part of a trial to determine if the unit could effectively automate the disinfection process. A heavy-duty submersible electrode assembly, installed within the contact chamber approximately 100 feet from the chlorine injection point, measures the ORP (oxidant demand) of the effluent. The unique probe design, which comes with a two year warranty, incorporates a 99.999% pure platinum sensing electrode and a porous Teflon liquid junction. These features allow the HRR system to effectively operate in a wastewater environment and measure 1 mV ORP changes, which is required for accurate control.

The Strantrol 890 combines plant flow and oxidative requirements to match chlorine feed rate to the changing oxidant demand in the system and to maintain a predetermined ORP setpoint (mV). The SloLogic control algorithm used by the Strantrol 890 was developed to mimic the actions of an operator. Utilizing the flow signal to calculate changes in lag time between the chemical injection point and the sensor location, the controller looks at deviations from ORP setpoint at a 10:2:1 time ratio. For example, if the lag time is 10 minutes, the controller looks at the deviation from setpoint during the whole 10 minutes, during the last two minutes, and during the last one minute. Then the SloLogic processor averages the verdict of all three factors, determines how much to change output and in which direction, and then executes the change on the 10 minute interval.

Results

Upon the initial installation of the demonstration unit, daily bacteriological samples were taken for E-Coli analysis. At the same time, total chlorine residual of the final effluent exiting the contact chamber was measured using a colorimetric handheld analyzer. These two measurements were used to optimize the ORP setpoint of the HRR controller to ensure discharge compliance and to minimize chlorine consumption.

The setpoint, determined to be 425 mV, was entered into the Strantrol unit, which controlled the output from the gas chlorinator to maintain the setpoint or the oxidative strength within the contact chamber. Furthermore, minimum and maximum dosage setpoints where established and inputted into the Strantrol 890 to maintain chlorine feed during process upsets. Maintenance of the system simply involved weekly cleaning of the submersible ORP probe.

By automating chlorine feed to the contact chamber using the Strantrol 890 HRR unit, the amount of chlorine fed and ultimately discharged to Kelly Lake was significantly reduced. During the three and a half month trial period (May 15 to August 31, 2002), 4040 kg less chlorine was used compared to the same period in 2001, a 32% decrease, adjusted for flow. Furthermore, the average chlorine residual measured over the same period was reduced from 0.82 mg/L to 0.44 mg/L while in compliance with E-Coli discharge limits under the Certificate of Approval during the entire trial period under automated control; this proved that controlling oxidant feed to meet demand can eliminate the need to overfeed chlorine.

The Sudbury Wastewater Treatment Plant purchased the Strantrol 890 HRR controller with the automatic probe wash option in September 2002. Plant management estimates that chlorine savings alone will help pay for it in approximately 13 months.