

# COMPOUND COSTS OF INSTRUMENT INACCURACIES

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## **Case Study**

A wastewater treatment facility custom installed a probe-type, chlorine residual analyzer approximately 100 ft (30 m) downstream from the chlorine injection point to monitor the wastewater effluent. The probe-type analyzer was selected for its low cost (approximately \$2,000), simple installation (directly in the process stream without sample pumps or piping), and quick response time.

## **Manufacturer's Recommendation vs. Custom Installation**

The manufacturer of the probe-type analyzer recommended a special flow block installation with long sampling lines. Because the manufacturer's recommended installation setup would increase the response time and installation costs, the wastewater treatment facility decided to choose a custom installation. A manufacturer representative reviewed the facility's custom installation, had the installation checked with the factory, and granted approval of the probe's installation.

## **Problem Statement**

After installation and startup, the analyzer's output was erratic compared to field analysis tests of the effluent's chlorine residual. Staff began to troubleshoot the analyzer.

## **Calibration Practices**

During the calibration process, staff used a stirring plate in a process sample to simulate process flow. It was during this procedure that staff noted that chlorine residual analyzer readings varied while the stirring plate was running. It was observed that the analyzer was sensitive to changes in flow velocities. It was also observed that, as process flow varied in the effluent channel, the channel's flow velocity increased and decreased proportionally to the effluent flow. It seemed that the erratic readings of the analyzer were caused by process flow changes.

One solution was to ensure that minimum flow velocities were maintained at all times. Staff remedied this by lowering the probe deeper into the process flow where fewer velocity changes occurred. Although these changes were made, the probe's readings remained erratic, requiring staff's continued investigation of the analyzer's response.

Staff also recognized that, because there were no calibration facilities near the chlorine residual analyzer, staff were required to collect samples and transport them to the laboratory for analysis. Once the analysis was completed, staff returned to the analyzer with the laboratory results to recalibrate the analyzer.



**Manual Titration for Laboratory Analysis**

The time delay between the analyzer's reading at the time the sample was taken and the time it took staff to perform analysis in the laboratory before recalibrating was significant enough to have changes in the process, therefore producing errors in the analyzer calibration and analyzer output readings.

#### **Maintenance Practices**

While performing maintenance, staff noticed that the analyzer had collected grease and oil deposits on the membrane to the sensor. Oil and grease in the effluent was not visible. Staff made the assumption that the injection of chlorine to the disinfection process precipitated small amounts of oil and grease.

After the injection point, oil and grease remained suspended in the effluent and collected on the analyzer membrane. This required staff to clean the analyzer more often, thus increasing maintenance costs. In addition, it was found that oil and grease deposits caused the analyzer to report low chlorine residual readings.

All of these problems added to the inaccuracy of the analyzer over a 2-year period. During the time the analyzer was out of service, staff resorted to manual feed control based on effluent flow. This practice became a more accurate and reliable method of controlling the process than using the installed analyzer.

#### **Replacement Chlorine Residual Analyzer**

After struggling with trying to manage the residual chlorine analyzer for 2 years, it was removed from service and replaced with a more accurate and reliable analyzer. Data from the Instrumentation Testing Association's (ITA) performance evaluation report, *Chlorine Residual Analyzers for Water and Wastewater Treatment* (1990), was used to select the best analyzer for this application.



### **Chlorine Residual Analyzer Installation With Reagents and Laboratory Analysis Equipment**

The replacement analyzer cost approximately \$5,000 and was installed per the manufacturer's recommendations. Total installation costs exceeded \$20,000 due to special sample pumps, additional sample piping, and sample conditioning. The replacement analyzer was also installed in a small structure that contained equipment for laboratory analysis.

This laboratory equipment located at the analyzer installation site would eliminate errors in analyzer calibration.



**Inside Chlorine Residual Analyzer  
Sample Cell and Reagent Pump**

### **Lessons Learned**

It was learned that chlorine residual analyzer inaccuracies can be caused by

- Lack of proper maintenance;
- Lack of proper calibration;
- Human error in calibration procedures;
- Improper installation;
- Invalid sample point; and
- Inherent instrument inaccuracies.

After installation of the replacement analyzer, the treatment facility realized significant cost savings by having a more accurate and reliable chlorine residual analyzer. The replacement analyzer operated accurately and reliably for more than 8 years. The improved accuracy of the new analyzer realized cost savings in chemical use that exceeded the entire installation cost in its first year of operation.

### Accuracy Cost Analysis

Wastewater treatment facility staff observed that, as the accuracy of the chlorine residual analyzer decreased (or percent error increases), the cost of operating the disinfection facility increased proportionally.

An example of a wastewater treatment facility's cost of disinfection follows:

#### Assumptions

- Effluent Flow: 150 mgd
- Chlorine Disinfection Dose Rate: 7 mg/L
- Chlorine Residual: 5 mg/L
- Cost of Chlorine per lbs: \$0.124
- Sulfur Dioxide Dechlorination Dose Rate: 7 mg/L
- Cost of Sulfur Dioxide per lbs: \$0.112
- Because of the length of chlorine contact time, the initial chlorine disinfection dosing rate of 7 mg/L is reduced to the final chlorine residual of 5 mg/L.
- For the dechlorination dose rate, a 1:1 sulfur dioxide to chlorine is used with a 2-mg/L safety factor for a zero-chlorine residual.

#### Formulas

Pounds of chemical used per day = concentration of chemical in mg/L x flow in mgd X 8.34 (lbs/mil. gal)/mg/L (weight of 1 gal. water)

Cost of chemical used = Pounds of chemical used x cost of chemical per pound

Table 1 and the following graphs use the above assumptions and equations to show that total chemical cost for chlorination and dechlorination as a function of error in the chlorine residual analyzer. The error of the chlorine residual analyzer for this example is assumed to always output a chlorine residual error that is less than the actual chlorine residual.

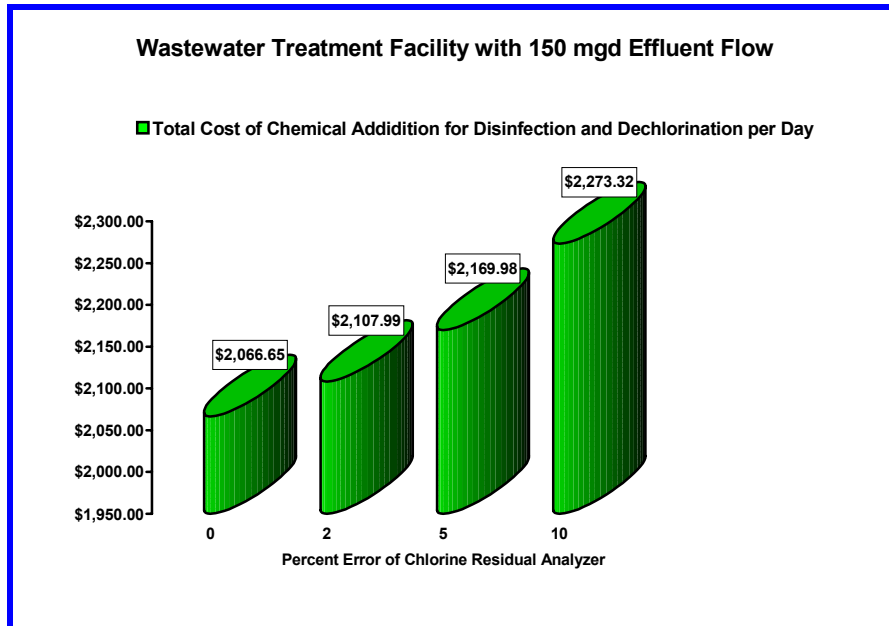
For example, the desired chlorine residual is 5 mg/L; but, for an analyzer with a 2% error, the chlorine residual analyzer output would read 4.9 mg/L. This erroneous output would cause the chlorination dosing equipment to increase the chlorine feed rate to match the desired 5 mg/L. The new actual chlorine residual would be 5.1 mg/L.

<b>Percent Error from Analyzer</b>	<b>Chlorine Used per day for Disinfection, lbs</b>	<b>Sulfur Dioxide Used per day for Dechlorination, lbs</b>	<b>Cost of Chlorine per lbs</b>	<b>Cost of Sulfur Dioxide per lbs</b>	<b>Total Cost of Chemical for Disinfection and Dechlorination per day</b>
0	8757	8757	\$0.124	\$0.112	\$2,066.65
2	8932.14	8932.14	\$0.124	\$0.112	\$2,107.99
5	9194.85	9194.85	\$0.124	\$0.112	\$2,169.98
10	9632.7	9632.7	\$0.124	\$0.112	\$2,273.32

<sup>1</sup> Table 1 does not include other chemical costs such as trimming dechlorination using sodium bisulfite or pH adjustments to the effluent using sodium hydroxide. In addition, Table 1 does not account for the error that occurs in the chlorine residual control loop if the facility is automated.

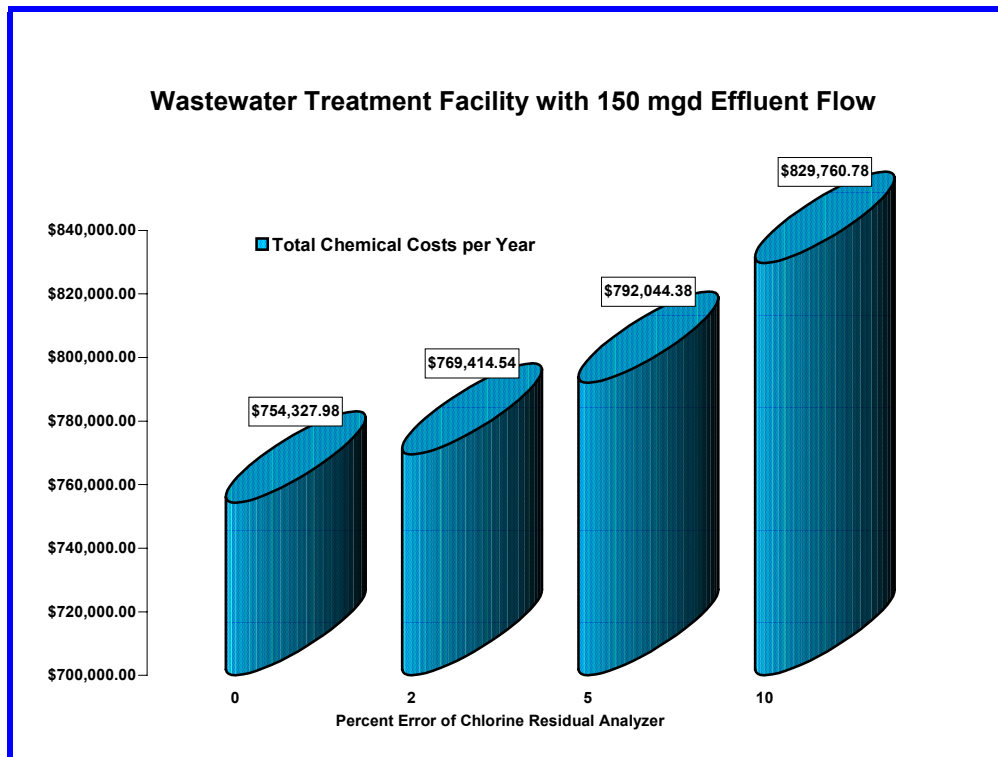
The following graphs depict the chemical cost for chlorination and dechlorination as functions of the amount of error as calculated in Table 1.

Graph 1 shows four columns, each representative of the total cost of chemical addition for chlorination and dechlorination per day compared to chlorine residual analyzer errors of 0, 2, 5, and 10%. The baseline column of \$2,066.65 at 0% error would be the minimum cost to chlorinate and dechlorinate if no error occurred when measuring the chlorine residual.



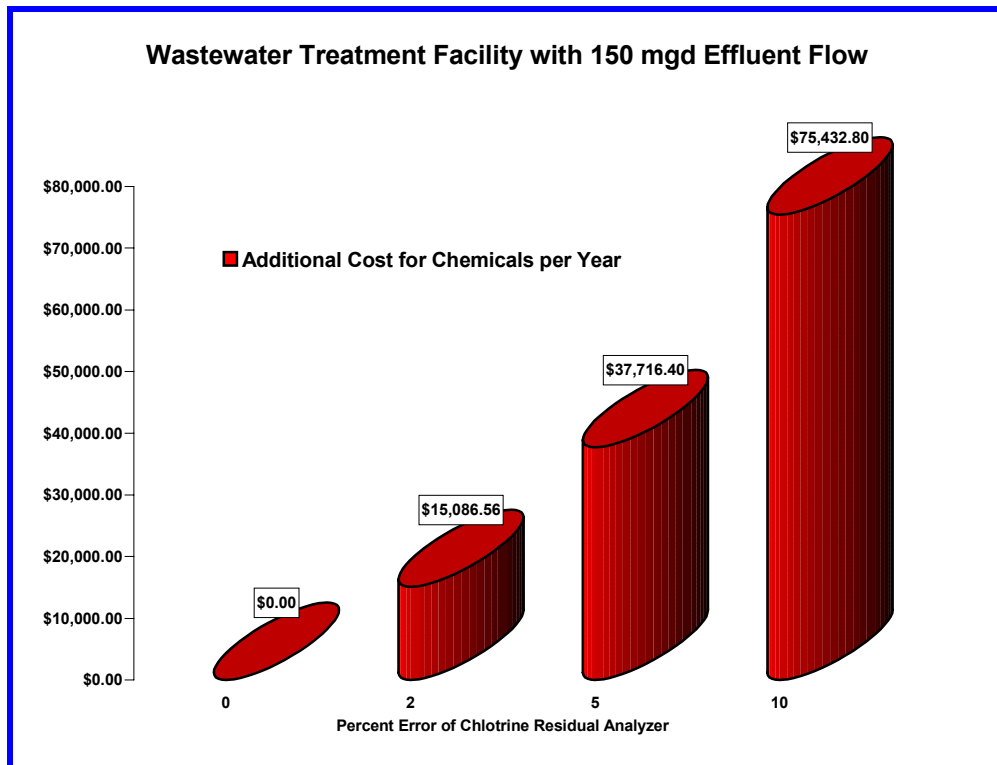
**Graph 1—Chemical Costs Per Day**

Graph 2 depicts the annual costs of chlorination and dechlorination compared to the percent error from the chlorine residual analyzer.



**Graph 2—Chemical Costs Per Year**

Graph 3 shows additional annual costs of chlorination and dechlorination as the percent of error increases in the chlorine residual measurement.



**Graph 3—Additional Chemical Costs Per Year**

**Conclusion**

The selection, installation, and maintenance of chlorine residual analyzers are crucial not only to permitting requirements but also to the cost-effective operation of chlorination and dechlorination at treatment facilities.

The cost of obtaining dependable and precise information on accurate and reliable chlorine residual analyzers is low when compared to the overall cost of facility operations on a year-to-year basis. Cooperative performance testing of instrumentation conducted by ITA allows utilities, consultants, industry, and regulatory agencies to be successful and cost effective in monitoring and controlling environmental processes. ▲

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