JACOBS

City of Leroy IL Water Treatment Plant Water Treatment Optimization Test Plan (DRAFT)

November 4, 2024, Rev 1

Project Background

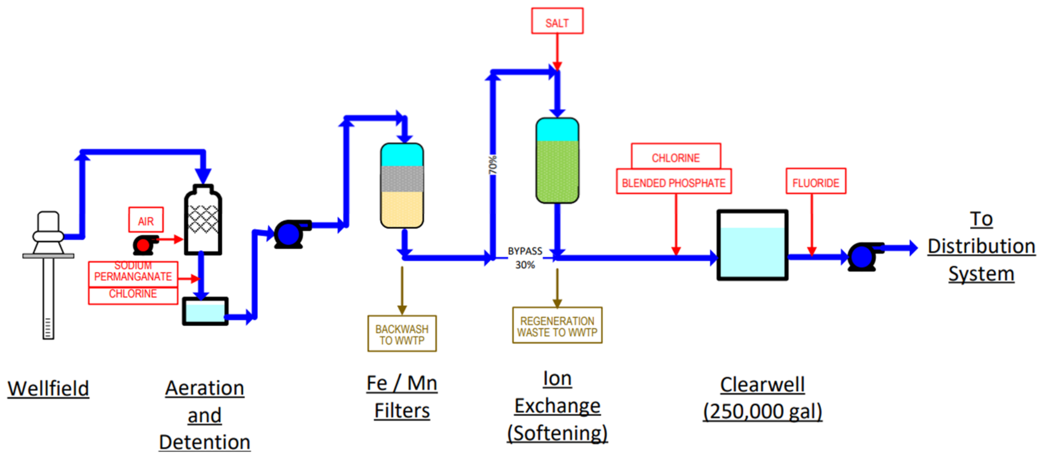
Jacobs recently completed a Water Treatment and Distribution System Water Quality study for Le Roy. The study recommended long-term improvements to the water treatment plant and distribution system. These improvements will take several years, and additional information is needed to finalize the water treatment design parameters.

The study also recommended investigating ways to improve water quality by optimizing the existing water plant, as an interim measure before long-term improvements can be made. This test plan summarizes the approach to optimizing the existing water plant.

The key issues that must be addressed in this study include:

1. Optimize iron, manganese and arsenic removal through greensand filtration, while reducing chlorine doses at the front of the plant.
2. Optimize ammonia removal through ion exchange softeners, while managing the ammonia and hardness levels in the bypass stream.
3. Add more chlorine after ion exchange and blending bypass water to reduce free ammonia and form a more stable chloramine disinfectant residual in the distribution system.
4. Reduce HAA and TTHM formation to below regulatory limits.
5. Increase total chlorine residuals in the distribution system to 1 mg/L or more to meet regulations.

This test plan outlines the test procedures, sample locations, number of samples and water quality parameters to be measured. This test plan will be reviewed with Le Roy and Illinois EPA before testing begins. A figure of the existing water treatment process is shown below for reference. The City recently increased the raw water chlorine dose to above 20 mg/L, finished water hardness to 140 mg/L as $CaCO_3$, and phosphate dose to 2.5 mg/L as PO_4 to improve lead and copper levels in the distribution system.



Testing Overview

Testing consists of four phases described in more detail in the subsequent sections. The four phases are summarized in Table 1 below.

Table 1. Test Plan Phases

Test Phases	Title	Purpose
1	Fe, Mn, and Arsenic Removal Optimization	Optimize Fe, Mn, and Arsenic removal while reducing pre-chlorine to reduce disinfection byproduct formation
2	Ammonia Removal Optimization	Optimize ammonia aemoval with IX media and reduce free ammonia after bypass by adding more chlorine before the clearwell.
3	TOC Removal Optimization	Optimize TOC removal with GAC media to reduce DBPs and increase total chlorine residuals in the distribution system.
4	Full Scale Testing	The most promising optimization results from the previous phases will be tested full scale

Phase 1 – Optimize Iron and Manganese Removal

The objective of Phase 1 is to optimize iron and manganese removal while reducing the chlorine dose to the aerated water pre-filtration. Reducing chlorine at the front of the water plant will reduce haloacetic acid (HAA) and trihalomethane (THM) formation to help comply with regulations. Reducing chlorine at the front of the water plant and adding more chlorine after ion exchange and bypass water blending will lower free ammonia in the distribution system to reduce nitrification potential and form a more stable chloramine residual.

The following bench test procedure is proposed. Full-scale testing may be implemented in Phase 4 to test the most promising bench testing results.

1. In the full-scale plant, measure dissolved oxygen (DO) and pH before and after aeration, to determine aeration effectiveness. Iron is oxidized with oxygen while manganese is best removed in dissolved form by catalytic media and permanganate. Compare measured DO to saturated DO levels at the measured temperature.
   i. Collect a raw water sample before aeration and chemical addition. Measure pH, temperature, DO, iron, manganese, arsenic.
   ii. Collect an aerated sample after detention and chemical addition under normal conditions and measure pH, temperature, DO, turbidity, ORP, total iron and manganese and dissolved iron and manganese, (8um, 0.45 um filtered sample). Measure arsenic after bench filtration. Compare DO level to saturation DO at the same temperature.
   iii. Collect a greensand filter effluent sample (before ion exchange) under normal conditions and measure pH, temperature, DO, ORP, total and dissolved iron and manganese, arsenic. Compare removal of iron, manganese and arsenic to that in step 1.ii.
2. In the plant lab, determine if supplemental oxygen, potassium permanganate and chlorine can improve iron and manganese removal.
   i. On the bench top, add supplemental oxygen with an aquarium bubbler at various doses/DO concentrations to a raw water sample (before aeration and chemical addition) and repeat the analyses in 1.ii after a similar detention time as the plant. The theoretical ratio is 0.14 mg/L of oxygen from aeration per 1 mg/L of oxidized iron, or about 0.7 mg/L for this raw water.
   ii. Add sodium permanganate at various doses from the current plant dose to double the current plant dose from 0.6 to 1.2 as Mn to the aerated raw water with the optimum oxygen from 2.i and repeat the analyses in1.ii after detention. The theoretical permanganate dose is about 0.94 mg/L per 1 mg/L of oxidized iron, or about 4 mg/L for this raw water, excluding the oxidized fraction from aeration.
   iii. If sufficient iron and manganese removal are not achieved, add various chlorine doses (from 2 to 20 mg/L) to the bench aerated raw water (optimum DO from 2i) along with optimum sodium permanganate dose (2ii) and repeat the analyzes in 1.ii to determine the minimum chlorine dose needed for effective iron removal. Ideally the chlorine dose will be reduced from current doses. The theoretical chlorine dose is 0.64 mg/L per 1 mg/L of oxidized iron.

Supplies required:

1) Dissolved oxygen analyzer
2) pH/Temperature/ORP analyzer
3) Sample bottles
4) Iron, Manganese, and Arsenic Test kits
5) Waste disposal kits for field tests
6) Chlorine test kits
7) Sodium permanganate and bleach (utilize plant supply if available)
8) Syringes and 8um / 0.45um filters (for assessing total vs. dissolved metals)
9) Aquarium bubbler
10) Stir bar
11) 2L jar
12) Pipettes

Up to 10 samples will be collected for external laboratory analysis to verify total and dissolved iron and manganese levels at the preferred dosing conditions. PACE analytical laboratories in Peoria, IL may be utilized given the City's past use of this laboratory. Jacobs will coordinate sample collection and delivery with the City.

Phase 2 – Optimize Ammonia Removal and Chloramine Stability

The objective of this task is to maximize ammonia removal with existing ion exchange softeners, and reduce ammonia going into the distribution system to maintain higher chloramine residuals while reducing DBPs.

Before testing begins, measure total and free chlorine, monochloramine, free and total ammonia, pH, and temperature at the following plant locations to establish a baseline:

- Raw water (free ammonia, pH, temperature only)
- Greensand filter influent
- Greensand filter effluent
- Ion exchange effluent
- Clearwell influent (after bypass blending)
- Clearwell effluent (high service pump discharge)

In addition, measure nitrite, iron and manganese in the greensand filter effluent and the clearwell effluent.

Subtask 2a – Ammonia Removal with Ion Exchange

With the current plant operation, collect free and total ammonia and hardness samples before and after one ion exchange vessel after regeneration until ammonia breakthrough. Review EPA data on ammonia removal through ion exchange. Note ion exchange influent ammonia levels and flowrate. Use this to determine sample frequency. During previous tests a large number of bed volumes were treated and no ammonia broke through. Use this as a guide so excess samples are not collected early in the softening cycle.

Subtask 2b – Chloramine Formation, Decay, and DBPs

1. Collect a water sample of ion exchange effluent, bypass water, and a sample after bypass blending (but before chlorine addition). Measure hardness, total chlorine, monochloramine, free and total ammonia in all 3 samples in the plant laboratory. Note bypass flowrate and total ion exchange flowrate.
2. Once preliminary chlorine doses are determined, onsite chloramine formation and decay testing will be conducted onsite.
    a. Add chlorine to each sample until a measurable total chlorine residual can be detected.
    b. Add chlorine to the bypass blended ion exchange water in a chlorine to ammonia-N ratio of 5:1. Measure total chlorine, monochloramine, free/total ammonia.
    c. Allow sample to decay in a brown glass jar and measure total chlorine, monochloramine, and ammonia every 1 to 6 hours for about 24 hours. Measure nitrite after 24 hours.
    d. After 24 hours, add chlorine in a chlorine to ammonia-N ratio of 5:1. Measure total chlorine, monochloramine and ammonia every 1 to 4 hours for about 24 hours. Measure nitrite after 24 hours.
    e. After 24 hours quench a sample with sodium thiosulfate and send to outside lab for analysis of TOC, TTHM and HAA.

Based on the results of this testing, the tests, steps a-e may be repeated with a lower initial ammonia concentration. For example, if the test indicates that total chlorine concentrations are above 4 mg/L after 2c and 2d, a lower ammonia concentration is required. The tests 2a through 2e can be repeated by collecting a sample of the bypass water and a sample of ion exchange effluent water and blending in a ratio to obtain a lower blended ammonia concentration.

Supplies required:

- pH/Temperature/ORP analyzer
- Sample bottles
- Test Jars (2L)
- Chemkey or Hach DPD kit with total and free chlorine, monochloramine, and free ammonia test kits (method used will depend on maximum detection limits)
- Hardness test kits (or utilize City lab).

Up to 20 TTHM and HAA5 samples will be analyzed as part of the testing protocol. Baseline water quality for pH, temperature, turbidity, and total chlorine levels will also be measured.

Phase 3 – GAC For TOC Removal

Le Roy water has high TOC concentrations. TOC reacts with chlorine to form disinfection byproducts such as THM and HAA that have regulatory limits. TOC also reduces chloramine residuals in the distribution system, leading to the inability to maintain the required chloramine residual. Therefore, removing TOC may be required to meet drinking water regulations.

GAC is a proven method to remove TOC. In the existing water plant, GAC could be placed after ion exchange and before final chlorine addition.

The objective of this task is to determine how frequently GAC media would require replacement to achieve adequate TOC removal. GAC media replacement is a major cost with the use of GAC. In addition, this task will determine chloramine stability and DBP formation at lower TOC levels.

Subtask 3a – GAC Capacity

A container of water from blended ion exchange water, before chlorine addition, will be sent to a lab for rapid small scale column testing (RSSCT). This test uses a miniature GAC column to rapidly test TOC removal capability and GAC replacement frequency. A breakthrough curve for TOC and UV absorbance will be developed. The GAC utilized will be Calgon Carbon F600 depending on availability.

Subtask 3b – DBP Formation

Using the test water sent to the external laboratory (~30 gallons, 6 x 5 gal carboys), DBP formation tests will be conducted with various TOC concentrations using both chlorine and chloramine. The results will indicate how much TOC removal is needed to use chlorine in the distribution system, and DBP formation with chloramine at lower TOC levels. The same lab running the RSSCT will conduct the DBP formation potential tests. The DBPs of interest will be TTHMs, HAA5, nitrate, and nitrite.

i. Use ion exchange effluent (before blending). Conduct simulated distribution system DBP formation testing with free chlorine at TOC levels of 4 and 2 mg/L. The ion exchange effluent will require dilution to obtain 2 and 4 mg/L TOC; or effluent from the RSSCT testing with GAC may be utilized if there is sufficient volume of water. Measure chlorine decay rate at each TOC concentration.

ii. Repeat i using chloramine at 4 mg/L monochloramine and TOC of 2, 4 and 6 mg/L (undiluted, blended ion exchange effluent). Measure monochloramine decay rate at each TOC concentration.

No on site bench testing is anticipated to be required for this phase of testing. Water quality analysis will be completed by the external laboratory for TOC, DOC, and UVA. SUVA values will be calculated based on the testing results.

Phase 4 – Full Scale Plant Testing

Based on the results of test Phases 1-3, full scale plant modifications may be made to verify test results. Illinois EPA will be kept informed on plant operational modifications and approvals will be obtained before testing begins.

These tests require a temporary change in chlorine dose to the aerated water and ion exchange effluent in the water plant. Implement the optimum dose of sodium permanganate to aerated water from Phase 1. Reduce chlorine dose to the aerated water, and add more chlorine after ion exchange, downstream of the bypass blending location. Use the results of Phase 2 to determine chlorine and permanganate doses.

In the full scale plant, add the optimum dose of sodium permanganate and chlorine from Phase 1 to the raw water. Add enough chlorine after ion exchange, downstream of the bypass blending sample location, to leave the plant with a total chlorine residual of 4 mg/L or less. Use the Phase 2 test results to determine chlorine dose after ion exchange. Adjust chlorine dose accordingly to produce an adequate total chlorine residual going into the distribution system.

This will be done for a short period of time to determine plant performance in removing iron, manganese, arsenic, ammonia. It will also allow determination of ion exchange capacity for ammonia when lower chlorine doses are used pre-filtration. Lower chlorine doses will increase ammonia concentration to ion exchange.

Additional full-scale tests may be identified based on results from Phases 1-3.

Subtask 4a – Sodium Permanganate Greensand Filter Optimization

This is a full scale water plant test to determine if adding sodium permanganate to the filter backwash water improves iron, manganese and arsenic removal by maintaining oxidized greensand media. A sodium permanganate injection port into the backwash supply water pipe will be needed, along with filter backwash programming changes.

i. Summarize recent existing plant data for iron, manganese and arsenic removal through greensand filtration.
ii. During a backwash, add sodium permanganate to the backwash supply water. This is done at a low backwash rate for a short time to fill the filter vessel with the sodium permanganate water. Allow the sodium permanganate to sit in the filter vessel for a prescribed time, then complete the backwash cycle.
iii. Measure total and dissolved iron, manganese and arsenic in the filter effluent.
iv. Repeat ii and iii with various sodium permanganate doses and detention times to optimize.

After the change in chlorine addition location and sodium permanganate optimization is made, collect water samples from various plant locations and analyze as described in the beginning of Phase 1. This will provide data to compare plant performance before and after the chlorine and sodium permanganate changes are made.

Subtask 4b – Ammonia Removal and Chloramine Stability

At the beginning of an ion exchange softening cycle in one vessel, measure hardness and ammonia in the ion exchange effluent (before bypass blending) until hardness breaks through. This will determine the ammonia capacity of the ion exchange softeners if less chlorine is added to the aerated water and more chlorine is added downstream of ion exchange.

Collect plant water before and after ion exchange, after bypass blending and after the clearwell. Measure hardness, total chlorine, monochloramine, free/total ammonia, iron, manganese. Compare results to those in Phase 2 bench testing.