DOWL

October 11, 2023

Mr. Nick McGann, P.E.
State Water Resources Control Board
Division of Drinking Water – Lassen Branch
364 Knollcrest Dr., Ste 101
Redding, CA 96002
(530) 224-3269

Subject: Plumas-Eureka CSD Arsenic Treatment Pilot Study Final Evaluation Report

Dear Mr. Nick McGann:

Please find the attached Pilot Study Final Evaluation Report for SWRCB review and acceptance of the pilot testing of Omni-SORB™ media through an Oxidation-Coagulation-Filtration process to remove iron, manganese, and arsenic from PECSD water system Well 2. Upon acceptance of the attached document, it is our intent to revise the previous engineering design to incorporate the piloted system/protocol in the full-scale facility and re-submit the facility design for technical review as part of a construction funding application.

Items not stated in the report which are relevant to the pilot study and/or full-scale facility design/operation include:

1. Consolidation – It has been previously determined in the Preliminary Engineering Report (Stantec, 2016) and the Arsenic Mitigation Feasibility Study (Farr West, 2017) that consolidation is not a viable option for the Plumas-Eureka CSD.
2. Best Available Technology – It was determined in the Arsenic Mitigation Feasibility Study (Farr West, 2017) that centralized treatment using an Oxidation-Coagulation-Filtration process is the preferred alternative for the Plumas-Eureka CSD.
3. Residual Handling/Disposal – Similar to the previous Water Treatment Plant (Farr West, 2018) engineered design, all backwash water will be placed into the community wastewater collection system and treated at Wastewater Treatment Plant 7 (WWTP 7). Additional engineering calculations related to the loading at WWTP 7 will be provided with the updated engineering design.
4. O&M Costs – All media and chemical supply costs will be detailed in the updated engineering design and included in the construction funding application.
5. pH Adjustment – Specific pH adjustment was not required for effective removal of the constituents of concern. However, DOWL will evaluate whether pH adjustment of treated water in the full-scale facility will be necessary to maintain compliance with the Lead and Copper Rule during the engineering design update phase.
6. Treated Water Storage – The Plumas-Eureka CSD does maintain sufficient storage to meet operating, emergency, and fire flow storage requirements.
7. Disinfection By-Products (DBPs) – There is a very low potential for DBPs to elevated as a result of the proposed water treatment plant. However, the updated engineering design will include a specific DBP analysis and engineering calculations (if appropriate).
8. Vessel Size – Per the 2022 Comment Response Letter, the treatment vessels will be upsized to 7-foot diameter vessels to allow for loading rates up to 6 gpm/ft^2. Per the letter, the design flow rate will be 410 gpm or 5.3 gpm/ft^2.

9. Adsorptive Media/Process – Per the findings of this pilot study, no adsorptive media process will be included in the full-scale facility.

There are numerous additional documents which evaluated alternatives available to PECSD and ultimately support this pilot study of Omni-SORB™ using an Oxidation-Coagulation-Filtration process in a central treatment facility. These documents include:

A. Pilot Study 1 (PureFlow, 2013)
B. Preliminary Engineering Report (Stantec, 2016)
C. Pilot Study 2 (Linkan, 2016)
D. Pilot Study 3 (Linkan, 2017)
E. Arsenic Mitigation Feasibility Study (Farr West, 2017)
F. Water Treatment Plant Design Drawings & Specifications (Farr West, 2018)
G. SWRCB Water Treatment Plant Engineering Design Comment Response Letter (Farr West, 2022)
H. Plumas-Eureka CSD Arsenic Treatment Plant Submittal Package (Farr West, 2022)

In addition to this Pilot Study Final Evaluation Report, all documents listed above will be uploaded to the construction funding application via the FAAST system.

Sincerely,

Luke Tipton, P.E., W.R.S
Water & Wastewater Business Leader

Attachment(s): Report on Results of Pilot Study and Recommendations on Findings

c: Jamar Tate – Plumas-Eureka CSD
John Rowden – Plumas-Eureka CSD
Steve Watson – State Water Resource Control Board

TECHNICAL MEMORANDUM

TO:	Plumas Eureka Community Services District
FROM:	Michael Persyn P.E.
DATE:	October 10, 2023
PROJECT:	De Nora Oxidation/Filtration Pilot Study 2023

REPORT ON RESULTS OF PILOT STUDY AND RECOMMENDATIONS ON FINDINGS.

Introduction

The Plumas-Eureka Community Services District (PECSD) currently operates groundwater wells for their drinking water system. These wells have issues with Iron, Manganese, and Arsenic contamination. Currently, the specified maximum contaminant limit (MCL) for Iron is 0.3 mg/L, for Manganese it is 0.05 mg/L and for Arsenic it is 10 micrograms per liter (µg/L).

DOWL was contracted to conduct a pilot study to determine the ability of the De Nora Omni-SORB Oxidation/Filtration Drinking Water Treatment System to remove Iron, Manganese, and Arsenic from the water pumped from Well 2. This treatment involves the oxidation of these metals to reduce their solubility in water and to precipitate a microscopic solid that can then be filtered.

Pilot System Set Up

Figure 1: Omni-SORB Oxidation/Filtration Treatment Pilot Assembly.

The pilot filter column treatment system was provided to us by De Nora and is capable of simulating the full-scale treatment plant performance. A photo of the pilot treatment system in use can be seen in Figure 1**Error! Reference source not found.**. The system is capable of monitoring the flow of water to each individual filter column and can be individually adjusted by flow control valves at the discharge of each column. Filter loading, given in the units of *gallons per minute per square foot* (gpm/sqft), is a calculation of water flow divided by column cross sectional area. This is the main flow related parameter we controlled and reported as it is vital in the design of the full-scale filter columns. The pilot columns were filled with 18 inches of Omni-SORB media and 18 inches of anthracite media on top of the Omni-SORB, these are the same depths as would be used in a full-scale design. A product brochure for the Omni-SORB media can be found in Appendix F.

A connection was made to the well pump discharge piping with a pressure reducing valve (PRV), a chemical injection manifold, and a static mixer. A 25-foot long, 5/8-inch diameter garden hose was connected in-between the static mixer and the treatment system to allow for increased reaction time for the oxidation of Iron, Manganese, and Arsenic with the dosed oxidant. A photo of the pressure regulator, injection manifold, and static mixer can be seen in Figure 2.

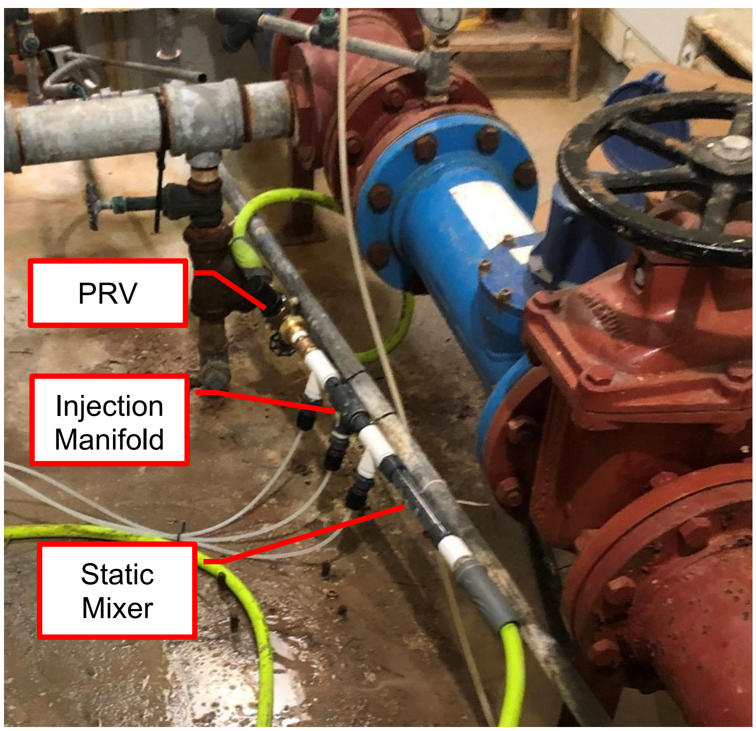

Figure 2: Connection point to well discharge. The locations of the Injection manifold, the PRV, and the static mixer are called out.

For the chemicals dosing, three LMI diaphragm chemical dosing pumps were utilized to dose the desired chemical at the desired rate. A photo of this can be seen in Figure 3. One pump was used to dose the oxidant, the second dosed hydrochloric acid (HCl) for pH control (if needed), and the third dosed coagulant. The chemical solutions for each pump were stored in 5-gallon buckets where the pump was positioned on top with the pump suction routed through the lid.

Figure 3: Chemical dosing pumps set up.

Chemical Constituent Testing

This pilot study included field testing using colorimetric and test strip equipment on site, and laboratory testing for field test verification. The field testing included tests for Iron, Manganese, Arsenic, Chlorine, Orthophosphate, and pH. For the Iron, Manganese, Chlorine, and Orthophosphate testing, the LaMotte Smart 3 Colorimeter was used with the appropriate reagent system. Arsenic was tested using the Industrial Test Systems Quick Arsenic II Test Kit that utilized reagents and test strips. For pH, a LaMotte Tracer Pocket Tester pH probe was used.

The Iron test used the Phenanthroline Method reagent system returned results for reduced Iron (Ferrous Iron, Fe^{2+}), oxidized Iron (Ferric Iron, Fe^{3+}), and total Iron (Ferrous + Ferric). This test allowed us to assess our process's ability to remove Iron. It also allowed us to verify the effectiveness of our oxidizer to convert Ferrous iron to Ferric iron by sampling water that had been dosed with the selected chemicals, traveled through the reaction hose, just before it entered the filter columns.

Manganese testing used the 1-(2-Pyridylazo)-2-Napthol (PAN) Method reagent system. The test returned results for total Manganese only and was implemented for the raw water from the well and the filtrate from the end of the treatment system to assess Manganese removal. During the Potassium Permanganate oxidant trials, the test was also used to verify oxidant dose pre-filter.

Chlorine testing using the DPD tablet (diethyl-p-phenylenediamine) Method reagent system was conducted to monitor free Chlorine, combined Chlorine, and total Chlorine throughout the process to ensure during Sodium Hypochlorite dosing that a free Chlorine residual was present.

Arsenic was tested in the raw water and the post treatment filtrate. In this test, Arsenic compounds in the water sample are converted to Arsine (AsH_3) gas by the reaction with Zinc and Tartaric Acid. The Arsine gas reacts with the Mercuric Bromide on the test strip to form mixed Mercury halogens (such as AsH_2HgBr) that appear with a color change from white to yellow or brown. The color on the strip is compared with a color chart to assess Arsenic concentration. The test can detect Arsenic from <1 µg/L to >160 µg/L

Lastly, later in the pilot testing, Orthophosphate concentrations were tested for. This testing used the Ascorbic Acid Reduction method for the Smart3 Colorimeter. Orthophosphate was tested for in the raw water from the well and the filtrate from the end of the treatment system to assess Orthophosphate removal.

The specific procedures for these tests and the manuals for the equipment used can be found in Appendices G, H, and I.

Pilot Plant Performance Results

The pilot was split into two different testing protocols based on their oxidant. The two events were the use of Sodium Hypochlorite (NaOCl), common name bleach, as oxidant and then Potassium Permanganate ($KMnO_4$) as the oxidant. A subsequent reassessment of NaOCl with Polyaluminum Chloride (PAC) supplied name ChargePAC 60, coagulant was conducted.

In the first event using NaOCl as the oxidant, which caused a pH increase, hydrochloric acid (HCl) was dosed to lower the pH back to optimum. This iteration of the study had good success treating for Iron and Manganese to levels below the MCL as seen in the figures 4, 5, 6, and 7 below.

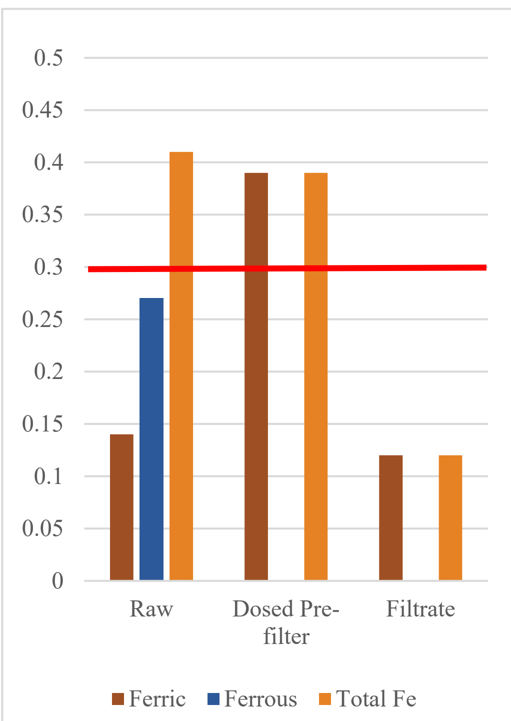

Figure 4: NaOCl Oxidized Fe Testing, 5 gpm/sqft

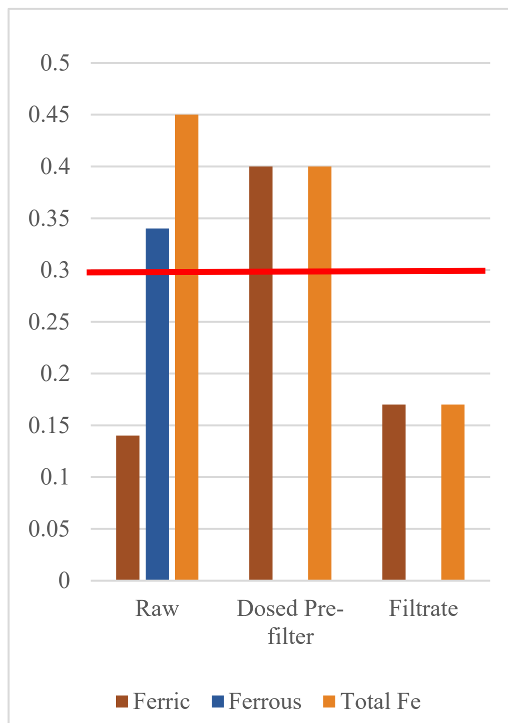

Figure 5: NaOCl Oxidized Fe Testing, 7 gpm/sqft

Iron removal field demonstration results can be seen in Figure 4 and Figure 5. Figure 4 had a calculated NaOCl dose of 3 mg/L and a HCl dose of 5 mg/L. Figure 5's iteration had a calculated NaOCl dose of 4 mg/L and a HCl dose of 4 mg/L. We can see that at 5 gpm/sqft and 7 gpm/sqft, Iron is removed well below the MCL of 0.3 mg/L.

In figure 6, the removal of manganese below the MCL was also achieved to within the margin of error (0.01 mg/L) for the same 5 gpm/sqft and 7 gpm/sqft iterations seen in figures 4 and 5.

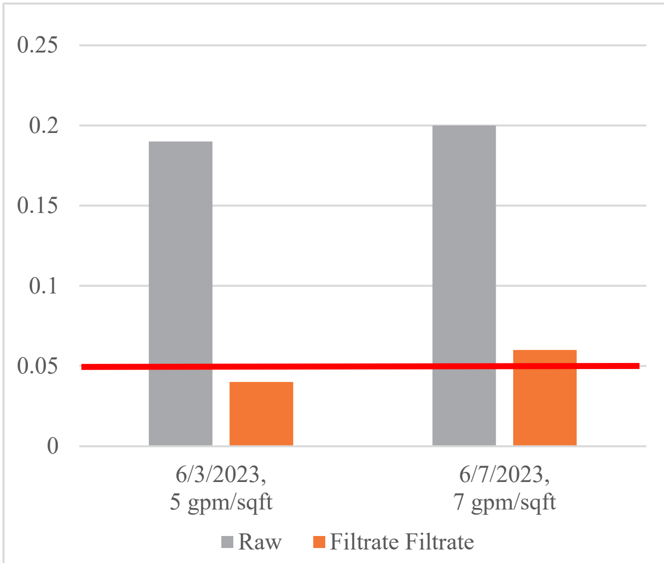

Figure 6: NaOCl Oxidized Total Mn Testing Results

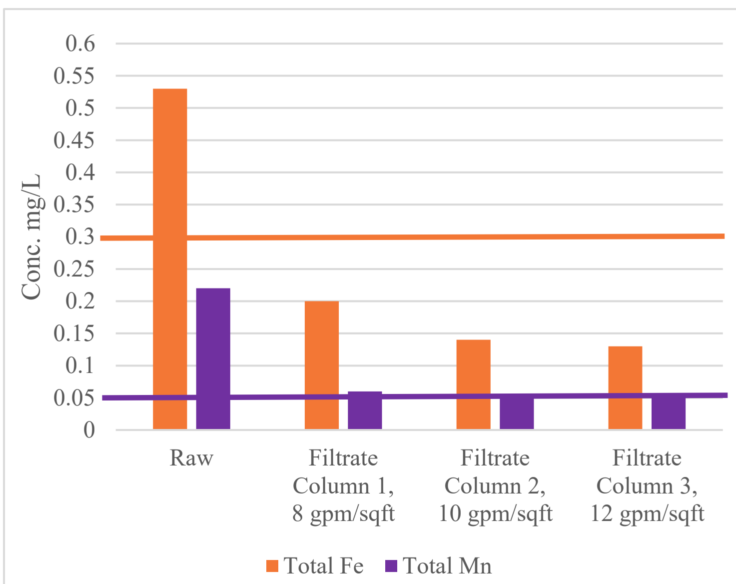

Figure 7: NaOCl Oxidized Total Fe and Total Mn, June 14th Flow Stress Test. MCL lines shown in matching color for respective metal.

A flow loading stress test was conducted where the flow rates to each column were varied. The loadings examined were 8 gpm/sqft, 10 gpm/sqft, and 12 gpm/sqft. As seen in Figure 7, the columns demonstrated effective treatment for Iron and Manganese at loading rates up to 12 gpm/sqft, which is higher than the specified loading rate of 7-10 gpm/sqft.

To this point, no treatment of Arsenic was observed. In an effort to increase the removal of Arsenic, Ferric Chloride ($FeCl_3$) was added to the chemical dosing. The theory being that a slight increase in Ferric Iron would provide more ability for the Arsenic to adsorb to the Iron and be filtered. In the testing, this was not found to be effective and detrimentally raised filtrate Total Fe concentrations. $FeCl_3$ was removed from use and is not recommended for use at full-scale.

While we successfully removed Iron and Manganese, we were unable to see any discernable reduction in Arsenic concentrations with the initial pilot testing of NaOCl as an oxidant. In all initial iterations the results of Arsenic testing were the same from raw to filtrate.

Potassium Permanganate ($KMnO_4$) was then assessed for its ability to oxidize iron, manganese, and arsenic to allow for removal. In the testing, Iron was able to be oxidized completely in all iterations and treated to below the MCL of 0.3 mg/L. However, all iterations where unable to attain Total Mn levels below the MCL of 0.05 mg/L. This was thought to be due to the additional Mn added by the $KMnO_4$ oxidant. The Mn concentrations for a filter run using $KMnO_4$ as the oxidant are shown in Figure 8. In this figure, the Mn concentrations throughout the pilot train are above the MCL shown as a red line.

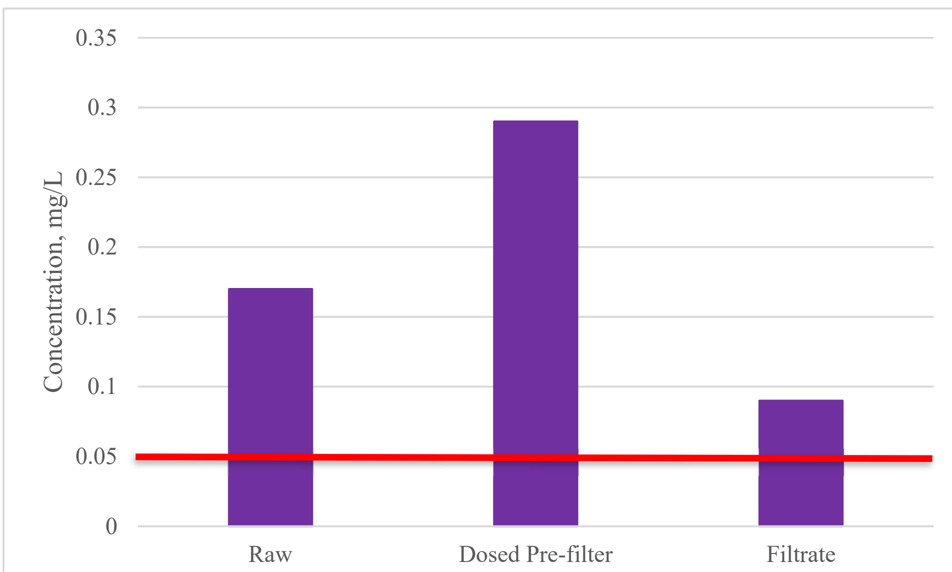

Figure 8: Total Mn, KMnO4 as Oxidant. Red line is the MCL for Mn.

During the same run in Figure 8, the raw water was tested for Orthophosphate (OP) and the concentration was over 3 mg/L, outside the range of the test. OP ions are known to compete with Arsenic (As) in adsorbing to the Iron precipitate where it can be filtered. This very high amount of raw water OP was the reason for the lack of treatment for As. Dosing of Polyaluminum Chloride (PAC) coagulant to remove the OP was initiated. Resulting Arsenic treatment was vastly improved and is shown in figure 9. The inclusion of PAC dosing continued for both $KMnO_4$ iterations and the final iterations reusing NaOCl.

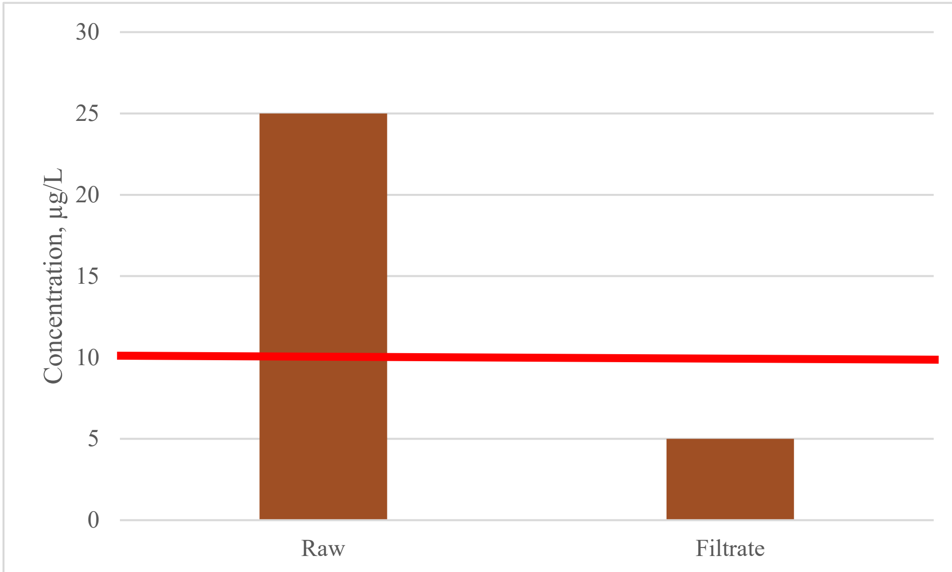

Figure 9: Arsenic treatment with the addition of PAC coagulant dosing. Red line is the MCL for Arsenic.

The determination to discontinue and not recommend the use $KMnO_4$ was made. While Fe, and As treatment were achieved, the inability to remove Mn to below the MCL rendered this oxidant not usable. Since the addition of PAC was so effective at removing OP allowing for As removal, its use was continued.

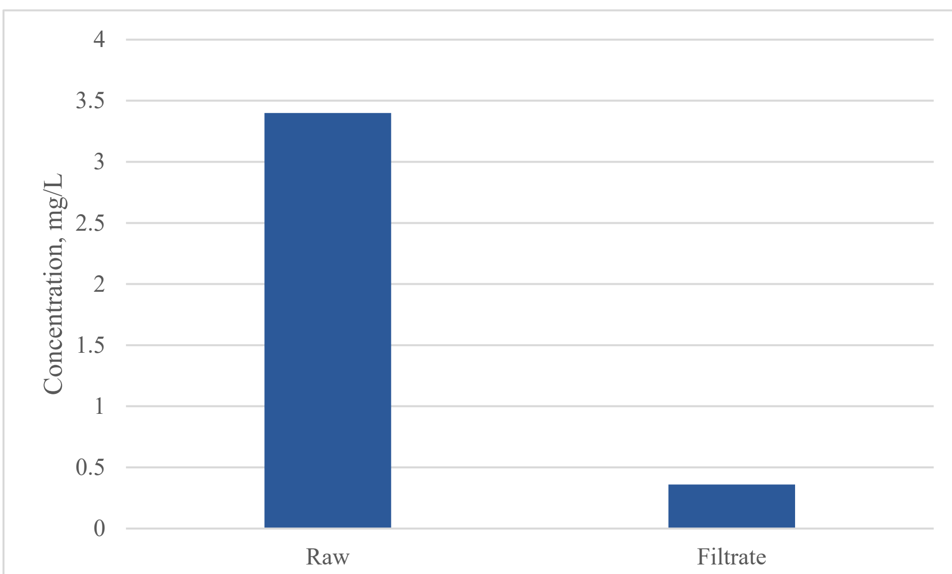

Figure 10: OP reduction using 2.5 mg/L NaOCl oxidant, 3.0 mg/L of Al from PAC coagulant, and a loading rate of 6 gpm/sqft.

The decision was then made to reassess NaOCl along with a minimum dose of PAC to attempt to treat for Fe, Mn and As. The As treatment results of testing and optimization are seen in Figure 10. The minimum doses identified to work the best for both treatment and runtime were

2.5 mg/L of NaOCl and 3.0 mg/L of Aluminum (Al) from the PAC coagulant. To calculate the concentration of Al from the PAC coagulant, the supplied PAC came with a certificate of analysis (CoA) that stated it had an Aluminum content of 5.25 weight percent. This weight percent was used as the basis for dosing calculations. Examples of the calculation and data logging spreadsheets for the pilot runs can be found in Appendix C. The runtime with this dosing regime was found to be approximately 6 hours. The runtime data can be seen in Figure 11.

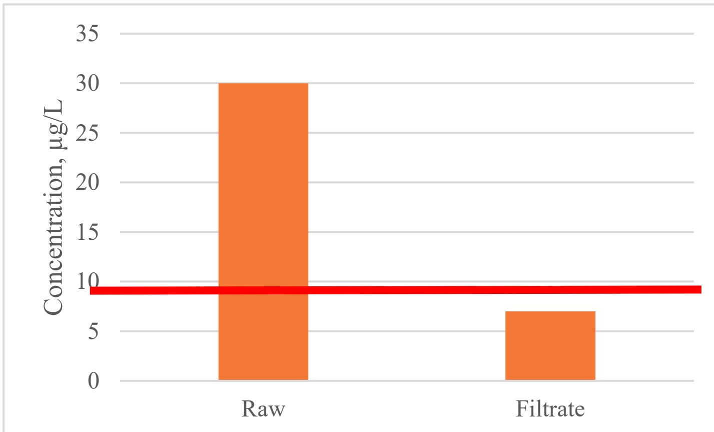

Figure 11: As reduction using 2.5 mg/L NaOCl oxidant, 3.0 mg/L of Al from PAC coagulant, and a loading rate of 6 gpm/sqft.

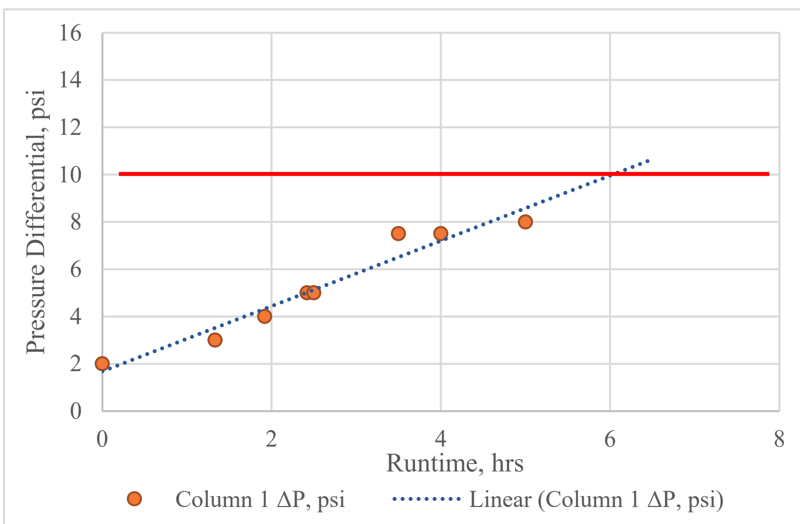

Figure 12: Pressure differential over time using 2.5 mg/L NaOCl oxidant, 3.0 mg/L of Al from PAC coagulant, and a loading rate of 6 gpm/sqft. A linear extrapolation is shown in blue to see total runtime of 6 hours at the 10-psi limit shown in red.

For these final dosing rates, the pH was seen to drop from 7.7 in the raw water to 7.0 in the filtrate. This filtrate pH of 7.0 is within the EPA's National Secondary Drinking Water Regulations of 6.5-8.5, so no further pH adjustment will be needed.

A final filtrate sample was sent to FGL Environmental Laboratory for analysis, which currently conducts the compliance lab sampling for the District, to confirm our field testing. The sample was tested for aluminum, iron, arsenic, manganese, and phosphate. A summary of the laboratory test results is summarized in Table 1 and the test report is available in Appendix J.

Table 1: Laboratory Test Results for Treatment Pilot Filtrate.

Constituent	Result	Reporting Limit	Units	MCL
Aluminum	ND	20	µg/L	1000
Arsenic	5	1	µg/L	10
Iron	ND	30	µg/L	300
Manganese	31.4	0.5	µg/L	50
ortho-Phosphate	0.31	0.3	mg/L	

ND=Not Detected

As seen in the above table, all the target constituents were treated to lower than maximum containment levels (MCL). Aluminum (which would have come from the coagulant) and iron were treated to levels the laboratory test could not detect. Arsenic was treated from a field-tested raw concentration of 30 µg/L to the laboratory tested concentration of 5 µg/L. With this, and all the other testing done, DOWL has determined that the well water used by our pilot study can be treated using the De Nora Omni-SORB process.

Final recommendation

It is the recommendation of DOWL that the De Nora Omni-SORB Oxidation/Filtration Treatment process will achieve the treatment goals required for Iron, Manganese, and Arsenic using the currently supplied well water. The recommended chemical doses found to achieve this are 2.5 mg/L of Sodium Hypochlorite oxidant and 3.0 mg/L of Aluminum from Polyaluminum Chloride coagulant. There is no pH adjustment required as the filtrate pH was found to typically be around 7.0 with the recommended dosing regimen. With a filter loading rate of 6 gpm/sqft, the filter runtime was determined to be approximately 6 hours, more than the minimum required cycle runtime of 4 hours. A summary of the design criteria recommendations can be seen in Table 1.

Table 2: Summary of Process Design Criteria Recommendations

Criteria	Recommendation
Oxidant, Dose	NaOCl, 2.5 mg/L
Coagulant, Dose	PAC, 3.0 mg/L Al
Filter Loading Rate	6 gpm/sqft
Dosed Chemicals Contact Time Before Filters	15 seconds