Manganese Filtration at the Home Farm Water Treatment Plant Using Biological Pressure Filtration

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Abstract: Manganese levels of the Home Farm Wells in Shrewsbury have exceeded the Secondary Maximum Contaminant Levels and Health Advisory limits. Various treatment options were evaluated and based on loading rates, removal efficiencies, and estimated costs, biological pressure filtration was selected. This paper provides an overview of the results of the pilot testing, design criteria, and funding assistance.

Background

The Home Farm Water Treatment Plant (WTP) in Shrewsbury, Massachusetts was originally constructed in 1989. Although the WTP is still fully functional, its treatment capabilities are limited to chemical addition and air strippers for VOC removal. The existing treatment plant has the capacity to treat six of the Town's seven groundwater sources. The Town would like to treat all its sources at this facility, but the existing plant is limited by the capacity of the high lift pumps, and is only capable of treating 6.0 million gallons per day. The seventh groundwater source is blended with the finished water of the treatment plant prior to entering the distribution system. The building itself includes a chemical room, laboratory, control room, and high lift pumps which pump into the distribution system. The air strippers are located outside of the existing WTP prior to the high lift pumps and chemical addition. Currently, the Town adds potassium hydroxide for pH adjustment, chlorine gas for disinfection, hydrofluorosilicic acid for fluoridation, and an orthophosphate for sequestering the high levels of manganese in their groundwater sources.

Manganese is present at all the Home Farm wells, with widely varying manganese levels from a low 0.03 parts per million (ppm) to a very high 0.7 ppm. To keep manganese concentrations below 0.3 ppm, the Town largely relies on blending water from the Home Farm sources with high levels of manganese with water from the Home Farm Wells with low manganese concentrations, as well as the Lambert and Sewell wells, which are offsite and have low concentrations of manganese. Recently, manganese levels in the raw water have been rising, and the Town is uncertain how long blending alone will be a viable option to manage manganese concentrations. Manganese concentrations in the raw water varies seasonally due to factors such as demand, groundwater levels, and drought conditions. It is important to note that although the Town has elevated manganese concentrations in raw water, iron levels are low.

The current treatment plant sequesters manganese, but does not have the ability to remove it from finished water. Sequestering attempts to prevent manganese from precipitating in the distribution system. The ability to sequester is pH and temperature dependent and can diminish in the water distribution system which can lead to tuberculated distribution pipes and stained plumbing appliances. In order to supply its customers with high quality water, the Town of Shrewsbury decided to upgrade the Home Farm WTP by adding filters to the treatment train in order to remove manganese rather than only sequester it.

Manganese is a secondary contaminant, and it does not have a maximum contaminant level; however, there are two noteworthy regulatory limits relevant to this subject. The Massachusetts Office of Research and Standards Guidelines (ORSG) has set a limit of 0.3 parts per million, which is why 0.3 ppm is the Town's current target manganese concentration in finished water post-blending. The EPA has set a secondary maximum contaminant level (SMCL) of 0.05 ppm, and the goal of the proposed filters is to keep manganese concentrations below the EPA's SMCL.

Historically, manganese levels have been high in the Town's raw water, particularly at Home Farm's Well 6-1. Over the past three years, only one sample taken from Well 6-1 tested under the ORSG limit of 0.3 ppm (Figure 1). In addition, manganese concentrations have been steadily rising. Because the process of designing and constructing a treatment plant takes several years, the Town proactively decided to apply for a loan from the Drinking Water State Revolving Fund (DWSRF) in 2015 with the goal of making the new filters operational before manganese levels became too high to control with blending alone. Tata & Howard prepared the PEF for the Town and it scored the second highest point total in the State. Since then, manganese levels have continued to rise in the raw water samples taken by the Town, while iron levels have continued to remain well below the EPA's SMCL.

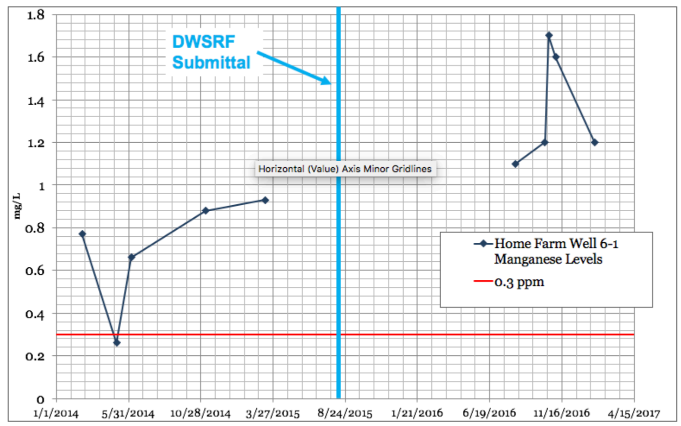
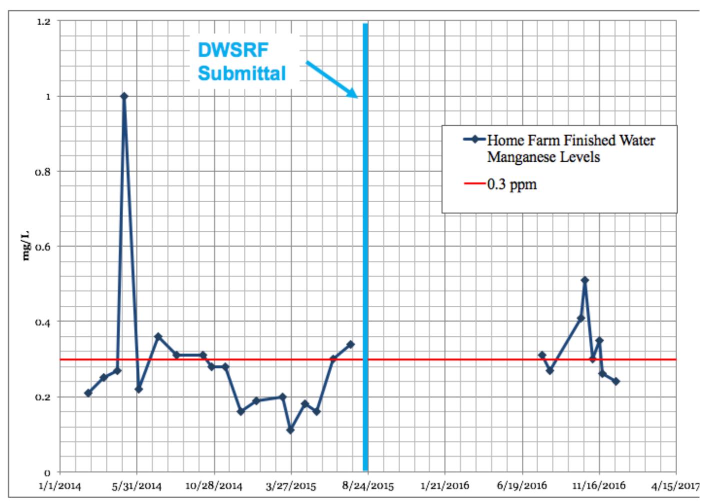


Figure 1: Manganese Levels in Raw Water at Home Farm Well 6-1

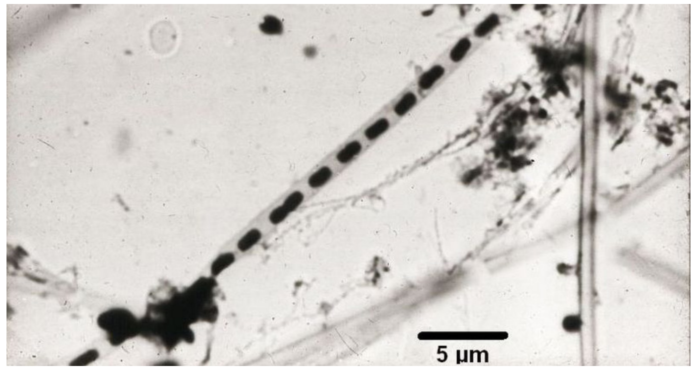


Manganese Levels in Home Farm Finished Water

Treatment Options

Three separate filter technologies were piloted. The first two were greensand and pyrolucite, both commonly implemented catalytic media options for treating manganese and iron. The third was the biological Mangazur® media, which is a new technology. The pilot testing was performed by Blueleaf, Inc., and was completed in two phases. The first phase tested the traditional catalytic media side by side, and took into consideration manganese removal as well as backwashing and pretreatment requirements. The second phase tested the Mangazur®.

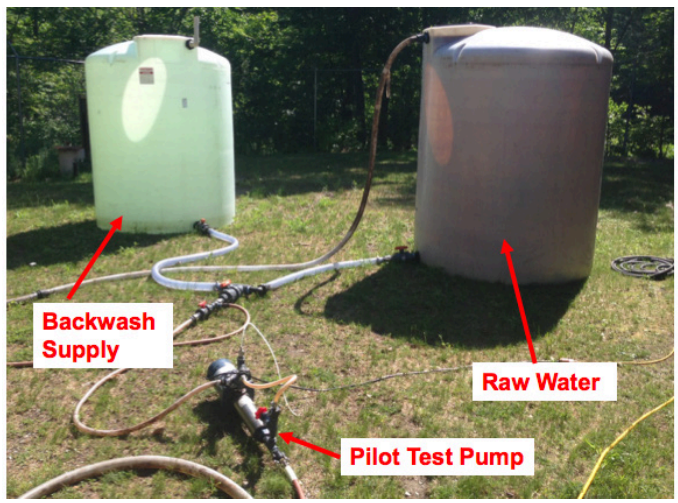
Mangazur® filter media provides an environment for growth of the microscopic organism leptothrix ochracea, which consumes manganese, and is naturally occurring in groundwater. Through consumption, the microbes oxidize the manganese to a state where it can precipitate onto the media. Unlike other media, Mangazur® media does not require regeneration due to the continuous growth of microbes within the filter. Mangazur® technology also does not require chemical addition for pre-oxidation, minimizing the amount of chemical required for the plant. One potential limitation of Mangazur® technology is that it removes high levels of manganese, but can only remove moderate levels of other secondary contaminants, such as iron. Removing high levels of iron would require an entirely separate treatment train known as Ferazur®, whereas a single pyrolucite or greensand system removes both secondary contaminants. Because the wells in the Town of Shrewsbury do not have elevated iron levels, this limitation is irrelevant, making the Mangazur® a very appealing technology.



leptothrix ochracea

Pilot Testing

The pilot testing was completed onsite with raw water taken directly from Well 6-1, the well with the highest raw water manganese levels. Initially, the source water was piped directly to the filters; however, because the Town required normal operation of their wells during pilot testing, the standard on/off cycles of the well pump made it difficult to collect continuous data. To obtain the most accurate results from the pilot testing, Blueleaf added a dedicated raw water storage tank and pump. The well pump filled the tank, and a transfer pump supplied a continuous flow from the raw water tank through the filters. Other equipment on site included a backwash water storage tank, and a trailer housing the filters and all necessary analyzers and instrumentation.



Backwashing of all three filters piloted was required due to headloss in the filters. The longer a filter is online and the filter media is removing a contaminant, the void space of the media decreases and headloss increases through the filter, eventually requiring backwash. For this project, individual trials were considered complete when the filters reached 10 psi of headloss, which is the point when a filter would require backwashing.

Pilot testing for the biological treatment was performed over several weeks. Important parameters tested for the biological filters were the optimal loading rate, pH level, dissolved oxygen level, the effect of a pre-oxidant, and the effect of a long shutdown. The results of the pilot tests indicated that all technologies were viable options to reduce manganese levels below 0.05 ppm; however, the biological treatment was the most efficient and attractive option.

During pilot testing of the catalytic media, several different loading rates were tested. Pilot testing of the catalytic media determined that a maximum loading rate of 3.6-4.5 gallons per minute per square foot (gpm/sf) would allow filter runtimes of at least 24 hours. Runtimes for the biological filtration technology were much longer, with run times in excess of 100 hours recorded for trial runs. In a few cases, the trial run was terminated prior to 10 psi of headloss because the excessive runtimes were no longer providing any critical information. In addition, the results of the testing indicated that although the Mangazur® does require a proper dissolved oxygen level and pH, it does not require a pre-oxidant, making the only chemical addition necessary for pretreatment potassium hydroxide. The catalytic media required potassium permanganate and sodium hypochlorite prior to the filters for pre-oxidation and regeneration of the media.

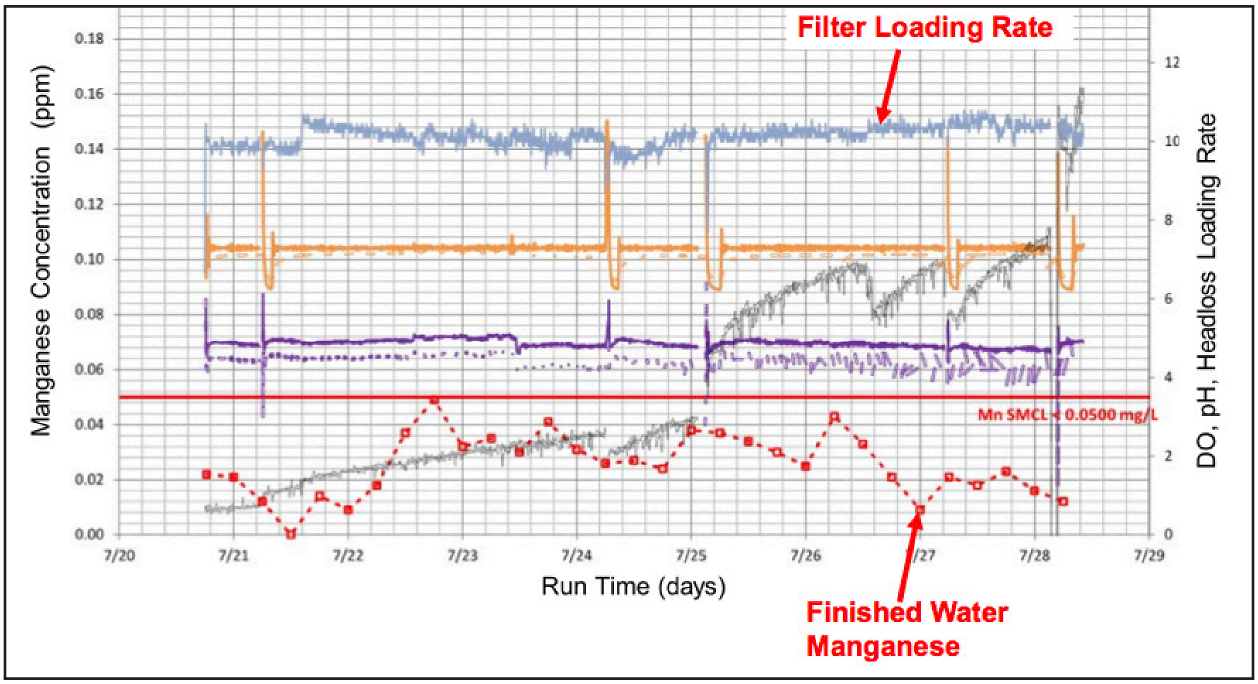


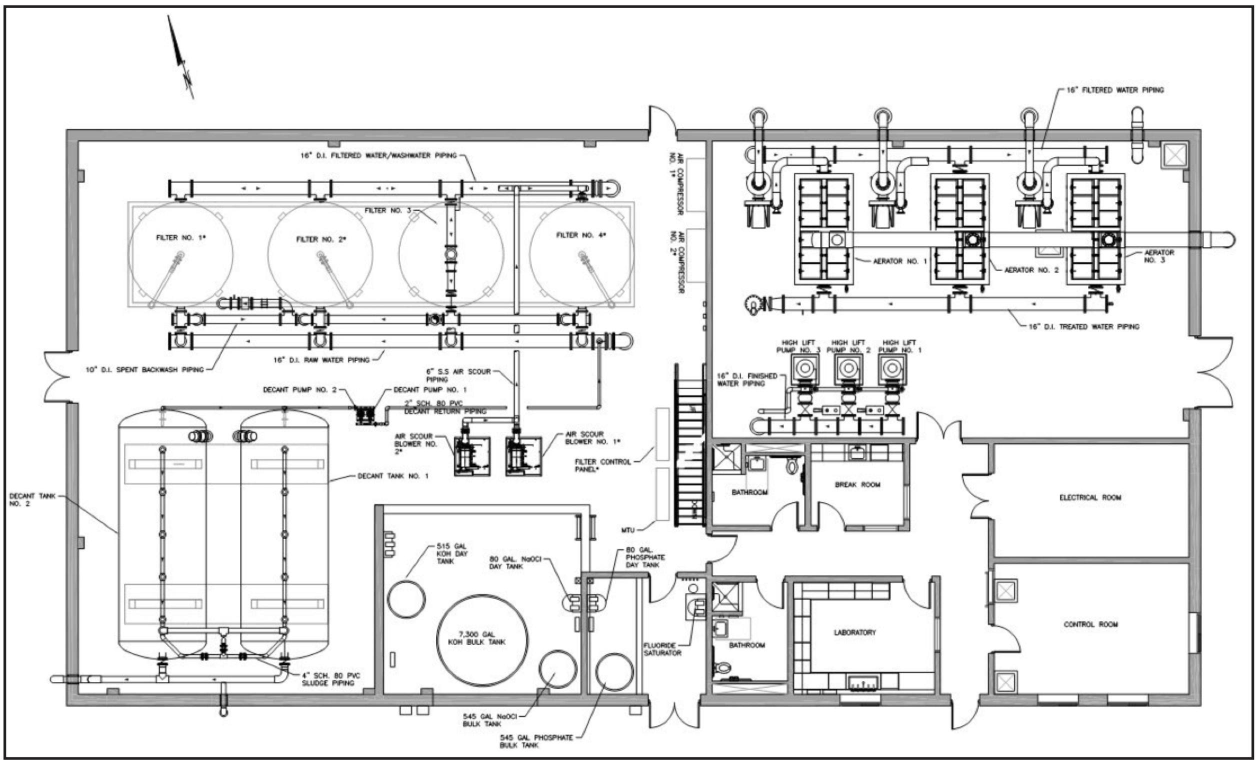
Figure 2: Pilot Test Results

After 13 trial runs, the optimal loading rate for the biological media was determined to be 15 gpm/sf (Figure 2). At this loading rate, which is three times more than could be achieved with greensand and pyrolucite media, the filters were still operating with runtimes over 96 hours, or four days. Note: the final MassDEP approved loading rate is 10.7 gpm/sf with all filters processing and 14.3 gpm/sf with one filter in backwash.

Final pilot test results indicated that Mangazur® was the best option for the Town of Shrewsbury, because of removal efficiency and the low operation and maintenance costs. Backwashing efficiency is a major benefit of the Mangazur® technology, especially for the Home Farm application. With loading rates over twice that of traditional catalytic media, only half as many filters are required. Additionally, runtimes prior to backwashing of each biological filter is 96 hours, versus runtimes of 24 hours for greensand and pyrolucite filters, for each biological filter; therefore, the Town would only need to backwash one filter each day with the biological filters, rather than eight filters every day, saving an eightfold amount of water. Also, the media requires no pre-oxidant, saving the Town money on chemicals. The Mangazur® technology offered no drawbacks for Shrewsbury, largely because of the low iron levels in the raw water, therefore, the Town elected to move forward with Mangazur® in the facility design.

A New Treatment Plant

Initially, the Town was only considering adding filters along with the required backwash holding tanks in a new building and utilizing the existing building. However, as the project progressed, it was determined that it would be more cost effective to replace the existing aging air strippers with new deep bubble aerators, rather than to continue to rehabilitate the existing equipment. An additional decision was made to replace all the chemical feed equipment, which is original from the construction of the existing WTP, and that it would be relocated into the new facility, leaving the laboratory, bathrooms and control room with SCADA the only functional aspect of the existing WTP. Since the existing building itself was also in need of rehabilitation, the decision was made to construct an entirely new standalone 7.0 million gallon per day (mgd) facility.



The new treatment plant will house a total of four 12-foot diameter filters. Only one filter at a time will be offline for backwashing. The filtered water effluent from the remaining three filters online will be the source of the backwash supply, eliminating the need for any backwash pumps or backwash supply holding tanks. A constant backpressure valve will keep the filtered water effluent pressure above 40 psi, the residual pressure required to backwash the biological filters. The facility will also house aerators for VOC removal. The aerators also provide a secondary benefit of marginally increasing the pH of the filtered water effluent. The facility will include two 5,000-gallon decant tanks for backwash waste, and a small submersible sewer pump station outside the building, which will discharge residuals from the backwash waste to the local sewer. The new chemical feed systems will still include potassium hydroxide, but the Town will utilize sodium hypochlorite instead of

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chlorine gas, sodium fluoride instead of hydrofluorosilicic acid to provide for greater operator safety, and a polyphosphate instead of an orthophosphate, since the purpose of the phosphate will be corrosion control instead of sequestering manganese. The plant also includes a 52,000-gallon two train clearwell to provide for 4-Log removal of viruses to meet the Groundwater Rule.

Although biological filtration has fewer pretreatment requirements, it does depend upon a proper pH and dissolved oxygen content. A minimum pH of 7.3 is required. Since groundwater pH is typically around 5.5, potassium hydroxide will be added to the water prior to the filters. In addition, the optimal dissolved oxygen level for manganese removal is 4.3. During trial runs, fluctuations in dissolved oxygen did reduce manganese removal efficacy. Therefore, an air injection mixer valve on the raw water filter influent will be installed to allow for control of the dissolved oxygen.

Looking Ahead

Design and operation of the biological media filters is similar to traditional media requirements, although startup requires unique considerations. It will take approximately one month to properly cultivate the leptothrix ochracea microbes to a concentration where they can adequately oxidize manganese. As an optional method of cultivating the microbes, established filter media can be introduced from an existing biological filter to speed up the growth of the microbes.

The Shrewsbury Home Farm Water Treatment Plant is estimated to cost approximately $14,900,000 inclusive of engineering and contingencies, of which approximately $1.2 million is for the biological filters. The Town received $13,985,000 from the Drinking Water State Revolving Fund (DWSRF) and $12,500 from the Commonwealth of Massachusetts for a Municipal Energy Technical Assistance Grant. Home Farm will also be a somewhat revolutionary treatment plant. While Mangazur® technology has been approved in one other municipality in Massachusetts, there are few treatment plants in the northeast using this technology, and of those treatment plants, none have a design capacity above 5.0 mgd. Home Farm has a much higher design capacity and will be the largest Mangazur® water treatment plant in the northeast once completed. The Mangazur® filters at Home Farm will have the second highest design capacity in the country, after a 26.0 mgd treatment plant in Lake Havasu City, Arizona.