Technical Memorandum

Date:	February 6, 2023
Project:	Preliminary Engineering Study for Fluoridation
To:	City of Spokane
From:	Consor
Re:	Fluoridation Ancillary Elements Technical Review

Introduction

This technical memorandum (TM) provides ancillary details associated with the potential implementation of providing fluoridated water to the City of Spokane (City) community. Impacts on water quality, specifically corrosion indices, considerations of downstream impacts to the City's Riverside Park Water Reclamation Facility wastewater treatment plant (WWTP) and considerations for non-fluoridated fill stations are summarized in this TM.

Water Quality

Finished water quality impacts of fluoridation, specifically corrosivity were assessed using Water!Pro™ software package to generate theoretical values for water equilibrium concentrations of dissolved lead and copper in the City's water distribution system. Alkalinity and hydrogen potential (pH) values both contribute significantly to the calculation of corrosion indices. Chemicals that change the pH or alkalinity of a water will therefore change the corrosion indices calculated for that water. Not all chemicals added to water impart significant acidity or alkalinity. Two of the three chemicals being considered for fluoridation would add acidity, which alters the relevant indices by consuming alkalinity, while the third is neutral.

Using fluorosilicic acid (H_2SiF_6) to achieve the desired fluoride level will consume about 2.1 milligrams per liter (mg/L) of alkalinity. Using sodium fluorosilicate (Na_2SiF_6) will consume about 1.4 mg/L of alkalinity. Using sodium fluoride will not impact pH or corrosion indices. Although sodium fluoride is a basic salt and the pH of saturated sodium fluoride solution is around 8.5, adding the small quantities of saturated sodium fluoride solution required for the desired fluoride concentration will not add sufficient alkalinity to measurably alter any of the parameters used to calculate corrosion indices.

The amount of change in pH that results from chemical addition depends not only on the acidity or alkalinity of the chemical added to the water but also on the buffering capacity of the water being treated. Of the seven wells used by the City, the Ray well has the highest buffering capacity while the Grace and Nevada wells have the lowest buffering capacities.

Prior to addition of any chemicals (including the chlorine gas for disinfection) most of the wells have neutral or slightly positive values for the Langelier Saturation Index (LSI). The LSI is a calculated number used to predict the calcium carbonate stability of water. It indicates whether the water will precipitate, dissolve, or be in equilibrium with calcium carbonate. The LSI is expressed as the difference between the actual system pH and the saturation pH.

$LSI = pH\ (measured) - pH_s$

- For LSI > 0, water is super saturated and tends to precipitate a scale layer of $CaCO_3$.
- For LSI = 0, water is saturated (in equilibrium) with $CaCO_3$. A scale layer of $CaCO_3$ is neither precipitated nor dissolved.
- For LSI < 0, water is under saturated and tends to dissolve solid $CaCO_3$.

If the actual pH of the water is below the calculated saturation pH, the LSI is negative, and the water has a very limited scaling potential. If the actual pH exceeds pHs, the LSI is positive, and being supersaturated with $CaCO_3$, the water has a tendency to form scale. At increasing positive index values, the scaling potential increases.

In practice, water with an LSI between −0.5 and +0.5 will not display enhanced mineral dissolving or scale forming properties. Water with an LSI below −0.5 tends to exhibit noticeably increased dissolving abilities while water with an LSI above +0.5 tends to exhibit noticeably increased scale forming properties.

The Grace, Nevada and Ray wells have slightly negative LSI. The LSI values after fluoridation with both fluorosilicic acid and sodium fluorosilicate will be lower than current operations. Using the Water!Pro™ water quality model, we estimated the changes in water quality parameters that may be anticipated from adding either fluorosilicic acid or sodium fluorosilicate to the water from each of the City's seven wells, in addition to the chlorine gas already added.

Adding fluorosilicic acid will reduce the pH of the Ray well water by about 0.08 pH units while the pH of the Grace well water my decrease by as much as 0.28 units. This will reduce the LSI of the water from those wells by about 0.1 units for the Ray well and as much as 0.3 units for the Grace well. Using the City's typical chlorine dose of 0.3 mg/L, all seven of the wells will have a negative LSI after addition of sufficient fluorosilicic acid to achieve 0.7 mg/L Fluoride. Grace well water would have the lowest LSI at -0.47. The water from the Central well will have the highest LSI value at -0.07. If chlorine doses higher than 0.3 mg/L are used, this will decrease the LSI values even more.

Using sodium fluorosilicate will reduce the pH of the wells by lesser amounts than using fluorosilicic acid. The Ray well water pH may be reduced by about 0.05 pH units while the pH of the Grace well water my decrease by as much as 0.120 units. This will reduce the LSI of the water from those wells by about 0.06 units for the Ray well by about 0.21 units for the Grace well. Assuming a chlorine dose of 0.3 mg/L, all seven of the wells will have a negative LSI after addition of sufficient sodium fluorosilicate to achieve 0.7 mg/L Fluoride. Grace well water would have the lowest LSI at -0.39.- The water from Central well will have the highest LSI values at -0.01.

The water quality model indicates that use of either fluorosilicic acid or sodium fluorosilicate in conjunction with the existing chlorine gas disinfectant will result in negative LSI values at all the wells. The LSI will be only slightly negative for Well Electric and Parkwater if those wells are treated with sodium fluorosilicate. LSI will be significantly negative for Grace and Nevada wells regardless of which of the two chemicals is used.

The water from Grace well currently has the lowest LSI of all the wells: -0.18 after dosing with chlorine gas at 0.3 mg/L. Well Electric, Parkwater, Central, Hoffman, and Ray wells will have higher LSI values than the current conditions at Grace well, regardless of which fluoride chemical is used. Nevada well will have higher LSI values regardless of which fluoride chemical is used.

Similar to the analysis completed as part of the 2016 City of Spokane Fluoridation Feasibility Study Update, the impact of fluoride addition was also modelled on a weighted blend of the water from the seven wells to estimate potential changes in the theoretical equilibrium values for lead and copper.

Neither fluorosilicic acid nor sodium fluorosilicate will have an impact on the dissolution of lead. As with the analysis done in 2016, the current study found that theoretical equilibrium values for lead concentrations are about 0.15 mg/L after disinfection and would be about 0.15 mg/L after addition of either fluorosilicic acid or sodium fluorosilicate. Using either chemical will have a slight but insignificant impact on the dissolution of copper. The current study found that theoretical equilibrium values for copper concentrations are about 0.17 mg/L after disinfection and would increase to about 0.18 mg/L after addition of either fluorosilicic acid or sodium fluorosilicate.

If either fluorosilicic acid or sodium fluorosilicate is chosen as the preferred chemical, the City may want to closely monitor the system in the months and years after the change for any signs that corrosion has increased or that scale deposits previously formed in the system have destabilized. Given that five of the seven wells will have LSI values approximately equal to the existing conditions at Grace well, and given the fact that the theoretical equilibrium concentration for lead will be unchanged and while the theoretical equilibrium concentration for copper will only increase by about 6 percent, there are unlikely to be significant changes in the distribution system with the use of either chemical, in spite of the negative LSI values calculated for all the wells.

Table 1 provides a summary of LSI of the for each of the City's wells before and after fluoridation.

Table 1 | Langelier Saturation Index Summary

Well	No Chemicals Added	0.3 mg/L Cl Added	0.3 mg/L Cl and Na_2SiF_6	0.3 mg/L Cl and H_2SiF_6
Central	0.12	0.06	-0.10	-0.17
Well Electric	0.17	0.13	-0.01	-0.07
Grace	-0.11	-0.18	-0.39	-0.47
Hoffman	0.09	0.04	-0.10	-0.16
Nevada	-0.08	-0.15	-0.34	-0.42
Parkwater	0.1	0.07	-0.04	-0.09
Ray	-0.04	-0.06	-0.06	-0.15

Wastewater Treatment Considerations

The City's Riverside Park Water Reclamation Facility was recently expanded to include the Next Level of Treatment (NLT), membrane filtration. This new filtration system will improve the quality of effluent that is released to the Spokane River.

Treatment impact considerations with fluoride within the influent wastewater is that conventional wastewater treatment such as electrochemical, precipitation, and adsorption methods are effective in removing fluoride owing to its ionic size and reactivity. Membrane technology as installed with the NLT is one of the newer technologies found to be effective in reducing fluoride to desired standards levels. Though removal is not required, at the concentrations targeted for the water system fluoridation are within potential ranges of naturally occurring would not impact the membranes similar to other inorganic chemicals found in groundwater supplied systems.

Further, the following is an excerpt from a study on impacts of municipal water system fluoridation on the aquatic environment:

> In conclusion, by using a mass balance approach, fluoridation-related changes in environmental concentrations of fluoride may be estimated from knowledge of municipal water management systems and data which are usually readily available from appropriate water authorities. Generally speaking, these changes will be minimal and, except when accompanied by serious industrial pollution, will remain below toxic levels recorded in the literature and recommendations by scientific authorities for the protection of the environment and human health. (Evaluating the Impact of Municipal Water Fluoridation on the Aquatic Environment; JOHN W. OSTERMAN, MD, SCD; AJPH October 1990, Vol. 80, No. 10)

Non-Fluoridated Fill Stations

The use of non-fluoridated fill stations is a potential solution for City customers who may prefer a non-fluoridated water source. This section reviews potential alternatives to provide non-fluoridated fill station treatment systems as well as planning level cost estimates for each.

Assumptions taken in this evaluation include that the groundwater sources do not currently contribute significant levels of naturally occurring fluoride or arsenic; fluoride will be dosed at each well to achieve the recommended 0.7 mg/L concentration in drinking water; and that each well will retain current treatment processes, including chlorination at the bottom of each well pump.

Methods for Non-Fluoridated Water

Locations for City customers to access non-fluoridated water can be provided through three methods. The first method is to select well locations near which customers could obtain pre-fluoridated (i.e., before it is treated with fluoride) water. The second method would be a customer point-of-use system located within their residences. The third method is to construct non-fluoridated fill stations that incorporate de-fluoridation treatment equipment to de-fluoridate water within the City's distribution system.

The following subsections will describe considerations for each of the three methods.

Pre-Fluoridation Fill Station(s)

This first method would provide a bypass before the well supply water is fluoridate at designated well stations and allow customers to fill self-supplied containers with non-fluoridated water. An important consideration is that the Washington State Department of Health (DOH) requirement that a fluoridated system must fluoridate all sources, including seasonal interties used longer than 3 months. Further coordination with DOH will be required should any non-fluoridated fill station option be pursued to understand potential permitting impacts. The City of Tacoma currently provides a single non-fluoridated well station for public use during restricted hours and would be a good resource should this option be explored further.

Table 2 summarizes this first method for the City to provide pre-fluoridated water to customers as needed, including the benefits and risks.

Table 2 | Bypass Method for Providing Non-Fluoridated Water

No.	Method	Capacity, gpm	Est. Cost	Benefits	Risks
1	SINGLE DESIGNATED NON-FLUORIDATED FILL STATION	N/A	\$50,000 to \$100,000 plus per well site depending extent of facility and site improvements(1)	• Little to no change to existing well system • Precedent at other cities	• Requires DOH coordination • Limited number of locations for customer access • Requires construction of fill station • Operation of well station needs to be assessed for an on-demand fill station

Notes:

1. No treatment equipment needed, includes an estimate on anticipated materials needed for connection to well discharge header, yard piping, backflow preventer, flow meter, and tap. Anticipated range of well facility building and site modifications/improvements.

Treatment Methods for Removing Fluoride (De-Fluoridation)

Table 3 lists alternatives for implementing treatment methods for providing de-fluoridated water to customers, including the benefits and risks for each alternative. The two main technologies used for de-fluoridation are activated alumina and reverse osmosis (RO), per AWWA M4 and summarized in this section. Other options exist but are not commonly used and are typically cost and resource prohibitive.

De-fluoridation can take place on a large scale with industrial-sized RO and activated alumina systems, or point-of-use (POU) treatment units exist that are commercial or residential-sized and de-fluoridate water as it exits a tap. These POU treatment units typically use RO technology.

Estimated costs are shown in Table 3 for customers to individually purchase residential POU systems on their own and for the City to provide fluoride removal treatment at a City fill station within the distribution system.

Costs for RO can vary widely depending on influent water characteristics defined through a complete water analysis and determination of required treatment capacity. For both industrial RO and industrial activated alumina fluoride removal systems, costs only include treatment equipment and do not include the costs for building facilities, site improvements, and other ancillary elements required for a fill station.

Table 3 | Treatment Methods for Removing Fluoride

No.	Method	Capacity, gpm	Est. Cost	Benefits	Risks
2	CUSTOMER POINT-OF-USE PURCHASE (RO)	5	\$250-\$500(1) per unit, does not include installation costs and modification of resident's plumbing, other ancillary	• No additional City infrastructure • Minimal City involvement • Easy customer opt-in • Customer receives de-fluoridated water at home	• All cost and responsibility on customers • City support (i.e., rebate program, etc.) may create mixed messaging • Can affect water aesthetics at tap (ex:

No.	Method	Capacity, gpm	Est. Cost	Benefits	Risks
			modifications and required permitting.		warm water, lower flow rates) • Different homes may require different POU systems
3a	REVERSE OSMOSIS (INDUSTRIAL)	600	\$500,000, per unit, does not include building facilities, site improvements, and other ancillary elements required for a fill station.	• More common • Can remove up to 90% of fluoride	• Operator and energy intensive • Large volumes of wastewater (~25% of raw water influent to waste) • Loses efficiency over time • System must be sanitized regularly to avoid bacteria, fungi, & mold • Effluent water has high pH • Permits likely required for disposal of concentrate
3b	ACTIVATED ALUMINA (INDUSTRIAL)	600	\$800,000(2) per unit, does not include building facilities, site improvements, and other ancillary elements required for a fill station.	• Smaller volumes of wastewater (~3% of treated water produced) • Wastewater from regeneration can be repurposed for irrigation (permits required)	• Operator intensive • Rare, not many applications to learn from • Pilot testing recommended • Chlorination before treatment causes fast degradation of alumina media • Media must be regenerated between runs • Regeneration uses raw water and creates waste stream • Requires operation of 2 units in lead and lag • Requires acid and caustic for pH adjustment

Notes:
1. For single RO unit, does not include resident plumbing modifications and installation.
2. Activated alumina treatment is not recommended due to chlorination locations at the bottom of well pumps.

Both of the de-fluoridation treatment options put additional cost on consumers to either drive and bring containers to fill up with non-fluoridated water from a provided location or purchase a point-of-use system to remove fluoride at their taps.

A key point to note about activated alumina is that chlorine degrades the activated alumina material. Therefore, de-fluoridation using activated alumina media is typically done before chlorination. Because the City currently chlorinates via injection at the bottom of each well pump, the use of activated alumina would require either significant re-configuration of well chlorination systems or frequent replacement of activated alumina media and is not recommended.

Non-Fluoridated Fill Station Conclusions

The methods summarized previously for providing the City customers an option to obtain non-fluoridated water have been evaluated as part of the Preliminary Engineering Study for Fluoridation. As fluoride is not shown to be detrimental to health, options to provide non-fluoridated water are provided in an effort to anticipate solutions should customers request options for non-fluoridated water.

Based on expected cost and operational and maintenance considerations, providing a designated non-fluoridated fill station at the City's well(s) is the simplest option for providing non-fluoridated water to City customers (Method No. 1). But providing a non-fluoridated fill station will require well operational considerations for meeting the needs of an on-demand fill station. A similarly simple option is for the City to recommend or create a program to provide countertop point-of-use treatment units (Method No. 2) for interested customers. Providing a de-fluoridated fill station will require the selection and maintenance of industrial treatment equipment.

The removal technologies described above (Methods No. 3a and No. 3b) are typically used for systems with high levels of naturally occurring fluoride that want to treat to levels below the secondary maximum contaminant limit (SMCL), which is well above the recommended concentration of 0.7 mg/L for a fluoridated system. As previously mentioned, activated alumina is not a recommended solution due to the current practice of dosing chlorine at the bottom of the well pumps. Using reverse osmosis to remove dosed fluoride from 0.7 mg/L to as low as possible is potentially not practical, as it would require a large and expensive treatment system and would create significant additional labor for operators.

The following are recommended next steps should the City opt to provide a non-fluoridated fill station or multiple fill stations for customers:

- Review system to select fill station location(s) and estimated demand at fill station(s),
- Reach out to other municipalities for questions and lessons learned,
- Decide how (or if) to charge customers at fill station,
- Contact DOH on permit implications for a non-fluoridated fill station in an otherwise fluoridated system,
- Determine potential chlorine concentrations and contact times at fill stations and options to mitigate, if needed, and
- Complete detailed design of new fill station(s), including connection location(s), yard piping, and pressure at fill nozzle(s).