Water Systems Engineering, Inc.

Date: October 18, 2013

Lab Report No. 19632

Thein Well Co.
P.O. Box 778
Spicer, MN 56288

Project Description: City of Henderson, MN; Well No.1; Samples Dated 9/31/13
Complete Well Profile (1)

Test Description:

The Complete Well Profile analysis is designed for comparative analysis of two samples, typically one static and one pumping sample. The Complete Well Profile utilizes a series of inorganic chemical and microbiological tests to identify fouling and corrosion issues with potential impacts on the operation of the sampled well. The tests include a number of inorganic chemical parameters such as pH, total dissolved solids/conductivity, hardness, alkalinity, oxidation reduction potential (ORP), bicarbonate, carbonates, silica, sodium, potassium, chloride, iron, manganese, phosphate, nitrate, sulfate, and total organic carbon (TOC). Biological assessment is designed to quantify the total bacterial population, identify two dominant populations of bacteria, assess anaerobic conditions, and identify the presence of iron related bacteria and sulfate reducing organisms. Also included are tests for Adenosine triphosphate (ATP), heterotrophic plate count (HPC), total coliform and E. coli coliform, and a microscopic evaluation.

Testing Procedures:

All laboratory testing procedures are performed according to the guidelines set forth in *Standard Methods for the Examination of Water and Wastewater* as established by the American Public Health Association (APHA), American Water Works Association (AWWA), and Water Environment Federation (WEF). Corrosion analyses are performed in accordance with the guidelines as set forth by the National Association of Corrosion Engineers (NACE). In general, these methods are approved by both the Environmental Protection Agency (EPA) and AWWA for the reporting of water and/or wastewater data.

Sample collection and shipment is the responsibility of the customer, performed according to protocol and procedures defined by the laboratory in advance of the sampling event with regards to the specific project and nature of the problem.

Disclaimer:

The data and interpretations presented are based on an evaluation of the samples and submitted data. Conclusions reached in this report are based upon the data available at the time of submittal and the accuracy of the report depends upon the validity of information submitted. Any recommendations presented are based on laboratory and field evaluations of similar fouling occurrences within potable water systems. Further investigative efforts, such as efficiency testing, site inspection, video survey, or other evaluation methods may offer additional insight into the system's condition and the degree of fouling present.

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ND - Not Detected NA - Not Applicable	**Sample #1 11:30** mg/l	**Sample #2 1:10** mg/l	**Detection Limits**
pH Value	7.40	7.51	NA
Phenolphthalein Alkalinity*	ND	ND	4 mg/l
Total Alkalinity*	384	380	4 mg/l
Hydroxide Alkalinity	ND	ND	4 mg/l
Carbonate Alkalinity	ND	ND	4 mg/l
Bicarbonate Alkalinity	384	380	4 mg/l
Total Dissolved Solids	670	645	1.0 mg/l
Conductivity (µm or µS/cm)	931	896	NA
ORP (mV)	200.0	189.0	NA
Langelier Saturation Index	+ 0.37	+ 0.49	NA
Total Hardness*	384	392	4 mg/l
Carbonate Hardness	384	380	4 mg/l
Non Carbonate Hardness	ND	12	4 mg/l
Calcium*	252	260	4 mg/l
Magnesium*	132	132	4 mg/l
Sodium (as Na)	45.1	43.5	0.02 mg/l
Potassium (as K)	4.4	4.5	0.1 mg/l
Phosphate (as PO4)	ND	ND	0.06 mg/l
Chlorides (as Cl)	11.2	11.2	2 mg/l
Nitrate (Nitrogen)	ND	ND	0.3 mg/l
Chlorine (as Cl)	ND	ND	0.02 mg/l
Dissolved Iron (as Fe2+)	ND	ND	0.02 mg/l
Suspended Iron (as Fe3+)	1.26	1.03	0.02 mg/l
Iron Total (as Fe)	1.26	1.03	0.02 mg/l
Iron (resuspended)	2.91	1.59	0.02 mg/l
Copper (as Cu)	ND	ND	0.04 mg/l
Manganese (as Mn)	ND	ND	0.1 mg/l
Sulfate (as SO4)	108	114	2 mg/l
Silica (as SiO2)	14.3	14.4	1.0 mg/l
Tannin/Lignin	ND	ND	0.1 mg/l
Total Organic Carbon (C)	0.6	1.3	0.0 mg/l

Bacterial Analysis:	**Sample No.1 11:30**	**Sample No. 2 1:10**	**Detection Limit**
Plate Count (colonies/ml)	7	11	NA
Anaerobic Growth (%)	<10	<10	NA
Sulfate Reducing Bacteria	Negative	Negative	NA
Fe/Mn Oxidizing Bact	Negative	Negative	NA
ATP (cells per ml) Initial	<1,000	<1,000	NA
ATP (cells per ml) 24 Hour	79,000	<1,000	NA
Total Coliform	Negative	Negative	
E. Coli	Negative	Negative	

Bacterial Identification	*Bacillus specie*	*Bacillus specie*

Microscopic Evaluation:

Sample No. 1, 11:30: Moderate visible bacterial activity, moderate amounts of iron oxide type biofilm, no crystalline debris, no sheathed or stalked bacteria noted.

Sample No. 2, 1:10: Low to moderate visible bacterial activity, low amounts of iron oxide type biofilm, no crystalline debris, no sheathed or stalked bacteria noted.

Observations and Interpretations:

Chemical analyses of samples taken from City of Henderson Well No.1 noted high levels of total dissolved solids, hardness, alkalinity, and calcium. The Langelier Saturation Index calculations yielded a positive number for the samples, indicating conditions that would favor mineralogical precipitation in the well. Sodium, potassium, and sulfate levels were slightly elevated in both samples. The oxidation reduction potential (ORP) readings fell within an acceptable range for ground water.

Total iron and resuspended iron are high in both samples. The resuspended iron result, which accounts for both chemically and biologically mobilized iron within a system, was shown to decrease only slightly with pumping. This may indicate chemically oxidized iron from the source formation, iron presence in the samples due to corrosion of the casing, pump, column pipe, and other well components, and may also indicate the presence of iron oxidizing bacteria in the well system not captured by the samples.

Biological analyses of the samples identified a relatively small resident bacterial population of low heterotrophic plate growth and visible microscopic activity. Adenosine Triphosphate (ATP) testing, a means of evaluating the total bacterial population present, identified acceptable populations present in both samples. However, comparison of the initial and 24 hour ATP results for Sample #1 showed a viable bacterial community is present, with abundant growth potential, which is significant for re-growth of bacteria in the well. The test results for total organic carbon (TOC), which is used as an indicator for bacterial stimulation and biofouling potential, was elevated for the aquifer sample. A high TOC level indicates the presence of a carbon based food source and biological community, and suggests a potential for biological fouling within the well and areas directly adjacent to it.

Testing for total coliform occurrence including E.coli specific coliforms, was negative for both samples. Anaerobic growth, as a percentage of the total population, was very low at less than 10% of the total bacterial population. Testing for sulfate reducing bacteria was negative in both samples.

Microscopic evaluation of the samples noted limited bacterial activity, with moderate amounts of iron oxide that was higher in Sample #1 (casing) and declined slightly in Sample #2 (aquifer).

Interpretations:

The chemical data suggests a congested well environment with regard to dissolved solids and mineral forming ions. Analysis of the two water samples found generally similar chemical concentrations, indicating consistent groundwater conditions, and the general effects of enriched formation water as it concentrates in the well. The water chemistry exhibits a strong tendency towards mineral deposition of carbonates and oxides, with sufficient hardness and mineral congestion to expect the development of mineral scale accumulation within the well and immediate formation. Calcium carbonate mineralization is likely.

The significant amounts of iron oxide within the samples are sufficient to indicate that active corrosion may be occurring. Reduced iron present in the aquifer may undergo chemical oxidation in the well environment, leading to the fallout of oxides within the well. The iron oxide buildup is likely heavy enough to accumulate in the well bore and to fill fissures and pore spaces, reducing flow and affect well production. In an open-hole completion it is not uncommon to have openings and fractures in the rock which do not experience adequate enough flow to prevent mineral and biological accumulations. These conditions appear to be concentrated in the interior of the well bore.

Recommendations:

Laboratory analyses of the two samples from the City of Henderson Well No. 1, have suggested some areas of concern sufficient to affect water quality and well production. The well shows signs of mineral fouling and significant iron accumulations. To address the identified concerns, this well would benefit from a combined mechanical and chemical rehabilitation, followed by a pH controlled chlorination treatment for disinfection.

Cleaning of the well should begin with removal of the pump and column pipe. Once removed, these components should be cleaned and evaluated for any need of repair or replacement. A video survey of the well should be conducted to ensure the structural integrity of the open borehole well and associated components. Given the depth of the well and the possibility of a large number of separate production zones, well work should be based on the results of the video survey to identify production zones and zones with obstructions at which to direct the rehabilitation efforts. Following pump removal, the well should be carefully brushed or jetted in an effort to remove accumulations within the casing and borehole that may reduce chemical effectiveness. The resulting debris should be strongly evacuated, with efforts focusing on the well bottom.

A chemical cleaning solution utilizing a mild mineral acid solution and biodispersant would be most effective. Use of 6% phosphoric acid, and 2% biodispersant such as Johnson Screens NW-310 would aid in improving cleaning efforts within the well. While the acid is required for dissolution of mineralogical deposits, the biodispersant is necessary to provide break-up and suspension of existing bacterial biofilm, and aid in its removal to waste. Actual volumes of acid

and bio-dispersant should be based on 1.5 times the standing well volume to account for treatment of the immediate formation.

Following chemical rehabilitation, disinfecting the well using a pH adjusted chlorination at 250 ppm is recommended. This process utilizes a chlorine enhancer to maintain the pH of 6.5 to 7.0, a level where the chlorine is most effective. A pH adjusted chlorination aids the penetration of the biofilm produced by the bacteria, and more effectively disinfects the system. Use of a chlorine enhancer such as Johnson Screens NW-410 would aid in improving disinfection efforts within the well. Full cleaning and disinfection procedures have been submitted under separate cover, titled “City of Henderson, MN; Well No.1; Well Rehabilitation Recommendations”.

Following cleaning and the return of the well to active service, you may wish to consider submitting monitoring samples to our lab. Monitoring water samples for chemical congestion and iron fouling can help ensure the long-term operating efficiency of the well.

Further investigative efforts, such as a pump test, additional video surveys, or other evaluation methods may offer additional insight into the condition and the degree of fouling in the well. If you would like full procedures, or need any additional information, please call our offices.

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