Shock Chlorination of Irrigation Wells to Reduce Iron-Related Bacteria and Emitter Clogging

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ABSTRACT

A test was undertaken to evaluate what effect super chlorinating wells might have in reducing emitter clogging. Two similar two-inch wells with iron concentrations around 10 ppm were used in the test. One well was shock treated with a concentration of 5,000 ppm chlorine and the other was not. Drip systems were installed at each well using three types of drip tape. The chlorinated well had no drop in flow rates, whereas the untreated well had 50% and 73% less flow then the original flow after 18 days.

INTRODUCTION

Iron in ground water used for irrigation can cause emitter, sprinkler and, even, well screen clogging. While the iron is still in solution (the ferrous state [Fe^{+2}]), the water poses little clogging potential. Once pumped out of the ground and exposed to increased oxygen levels, two changes can occur. The soluble Fe^{+2} iron can reduce to ferric iron (Fe^{+3}) which is insoluble and causes the characteristic reddish cast to water high in iron. Also, part of the iron can join with other elements and precipitate out of solution. The precipitated matter is heavier then water and will settle to the bottom of a container.

The iron present in the water can be expressed as:

$$\text{Total iron} = Fe^{+2} + Fe^{+3} + \text{precipitated iron compounds} \qquad \text{(Eq. 1)}$$

Typical water tests will only measure Fe^{+2} and total ionic iron (e.g., $Fe^{+2} + Fe^{+3}$). The ferric iron (Fe^{+3}) can then be calculated by subtracting out the Fe^{+2} value from the total ionic iron content. Since the precipitated iron is out of solution it is not measured in a water test. This precipitation action is the reason that total ionic iron levels of a water sample can decrease over time.

Clogging occurs in two ways. The minor way is that the precipitated iron and soluble ferrous iron can lead to clogging. However, the more serious way is that iron related bacteria (IRB) can complex with iron to form bacterial slime growths that lead to clogging. The IRB are microbial organisms that use iron in water as a host during their life cycle. These bacteria are more of a nuisance than they are a threat to human and animal health, like *e coli* is. Clusters of them can increase the brownish red or green

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color of water. The source of the IRB is often the water well, where high levels of iron (the fourth most abundant mineral on earth) allow it to breed. Water pumped from contaminated wells will re-infect water systems with IRB, where new colonies can begin to grow and multiply. Thus even when the irrigation system downstream of the well is treated with chlorine or other disinfectants, new colonies of IRB will be re-introduced from the well once pumping starts again if IRB in the well is not controlled, and the clogging potential continue. IRB can thrive on iron levels as small as Fe^{+2} = 0.2 ppm.

Two modes of treatment are often advised for drip systems that have water high in iron. The first mode, a biological one, is to use some sort of disinfectant to kill iron-related bacteria. If bacteria are eliminated then the clogging potential is greatly reduced since colloid iron does not pose a severe threat to clogging. The second mode of action, a chemical one, involves reducing all the Fe^{+2} to Fe^{+3} which can then be filtered out; without the iron the IRB can not thrive. One of the difficulties for irrigation managers is that the solution of choice for both modes of problems involves chlorine, which seems to blur the focus on whether chlorine is meant to be a disinfectant or a reducing agent. What is essential in the disinfectant mode is concentration and, to a lesser degree, contact time. What is important in the iron reduction mode is mixing time and filtration. Many filters in drip systems are placed just a few feet downstream of the chlorine injectors. Since piping is often sized to provide a velocity of 7 feet per second then in situations where a filter is only 5 feet away from the injector, a mixing time of only 0.7 second is available.

Canada and Australia have areas with ground water that has major iron problems that affect the life of water wells. Shock chlorination of wells with high IRB levels is a recommended practice (Williams, 2003). Shock chlorination treatments will decrease the number of iron related and other bacteria in a water well, but probably does not affect the iron content, which they live on, in the water. However, in one study in Canada iron levels did appear to be reduced as seen in figure 1 (Anonymous, 1999).

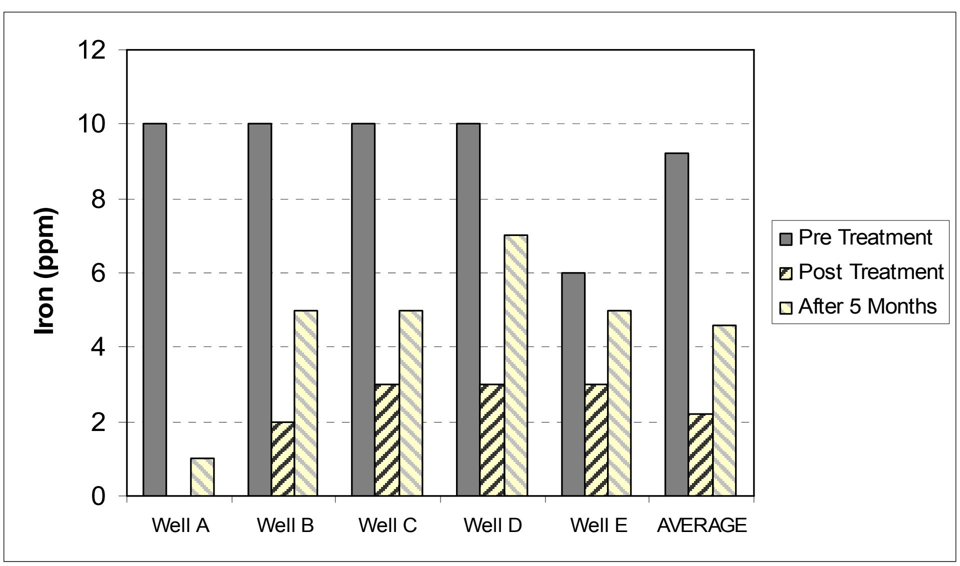

Fig. 1- Iron content of five different wells before, directly after and 5 months post chlorination.

Gilbert and Ford (1986) report water with total iron concentrations > 1.5 ppm is considered to have a severe clogging hazard. The iron content of underground water in Missouri, like many other states in the Midwest and mid-South, is generally high. A survey of 272 irrigation wells in southeast Missouri (SEMO) in 1987 showed the average iron content was 2.5 ppm, with Butler County wells averaging 4.5 ppm (Tracy and Hefner, 1993). Figure 2 is a map of SEMO showing the iron water content found in the wells. There is much variation in iron content within this area. About 13% of the farmers described the content of iron in their irrigation wells as "low", 71% as "medium", and 16% as "high" when asked to describe the iron level in an irrigation survey (Henggeler, 2003).

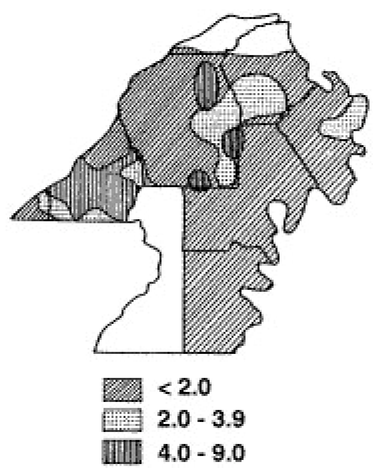

Fig. 2- Iron content in irrigation wells in southeast Missouri (after Tracy and Hefner, 1993).

The high level of iron in SEMO water wells causes problems for local watermelon and vegetable growers using drip irrigation. These users employ light-weight tape that is meant to be used just a single year and have minimal filtration and chlorine injecting capacity. In many years, especially in drier ones, the tapes clog before the season is over. One producer started a program of injecting chlorinated water into his small two-inch wells. He reported that the tapes afterward appeared to resist clogging for a longer period of time. The University of Missouri developed a well chlorination strategy based on this procedure.

MATERIALS and METHODS

An experiment was undertaken to measure the effectiveness of shock treating water wells with chlorine to reduce iron bacteria and clogging in drip irrigation systems. Two-inch wells cased in PVC pipe and originally jetted in to a depth of about 90 feet were used in the tested. The iron levels of both wells were high in iron with values around 10 ppm. One well was treated with a shock chlorination treatment, while the other was not treated and served as a check. Both wells were located on the University of Missouri Delta Center's Lee Farm approximately 150 feet from each other. Wells such as these can yield 100 GPM. Particulars concerning the two wells are shown in table 1.

Table 1. Year installed, current depth, standing water level and chlorination mix for wells in the test.

Name	Year Installed	Current Depth (feet)	Standing Water Level (feet)	Treatment	Chlorination Procedure	
					Water Added (gals)	Chlorine Added (oz)
L-8	1998	59.1	10.3	Treated	2.0	118
L-7	2003	44.0	10.8	Check	---	---

Initial water quality readings were taken that included iron (total & ferrous), oxidation reduction potential (ORP), chlorine (total & free), and pH. In addition, samples were tested for iron-reducing bacteria using BART testers.

Well L-8 was shock chlorinated on April 6, 2006 and again on August 28, 2006 in a procedure developed by Henggeler (2006). The procedure involves injecting a chlorine solution into the well casing under pressure. The concentration of chlorine in the pumped-in solution is such that the water standing in the well will be brought up to a concentration of 5,000 ppm chlorine. This concentration is higher then most recommendations, but was done on the suggestion of Dr. D.R. Cullimore a world renowned expert in the area of IRB (Cullimore, 2006). A 25-gallon sprayer equipped with a 12-volt pump was used to inject the chlorine solution into the well.

This solution is allowed to remain in the well for at least 24 hours before it is pumped out. At the end of August a drip irrigation system was installed at both well sites (Fig. 3). The system included a 12-volt, submersible pump, pressure gauges, an 8-psi pressure regulator, and a 5/8ths-inch water meter. Three types of drip tape were used and there were four laterals of 25 feet for each type. A cutoff valve was located at the head of each lateral line so that flow volumes could be isolated for the test. The particulars of the drip tapes are shown in table 2. No filtration or chemical injection during pumping was used in the test to purposefully accelerate clogging.

Table 2. Parameters of the two drip tapes used in the study.

Manufacturer	Tape Type	Nominal emitter flow (GPH)	x	k	Emitter Spacing (inches)	Total Amount of Tape (feet)	Number of Emitters
Netafim	Typhoon	0.18	0.48	0.059	12	75	75
Netafim	Typhoon	0.58	0.48	0.184	18	75	50

Flow rates were tested on a periodic basis for both systems. Flow was isolated to just the laterals of the individual tapes during the test. Flow rate was measured and pressure was recorded during the test. The flow rates were compared their original flows to determine the rate of clogging. The flow-head curves provided by the pump manufacturer overrated the capacity of the pumps, thus the seating pressure of the 8-psi regulators was not always met. Since operating conditions varied between test periods due to this and the level of charge on the battery at the time of the test, flows were adjusted for different operating pressures by using the *x* and *k* flow rate variables provided by the manufacturer. One of the tape types was constructed with fold-over seams used in the emitter design. These tapes allowed leakage around their connectors, so the results from them were not used in the test results.

Water samples were collected prior to the test and at weekly intervals after the test began. A sample was collected from the manifold which provided a water sample fresh from the well and another at the distill end of the tapes which would represent water that remains stagnant in the tape.

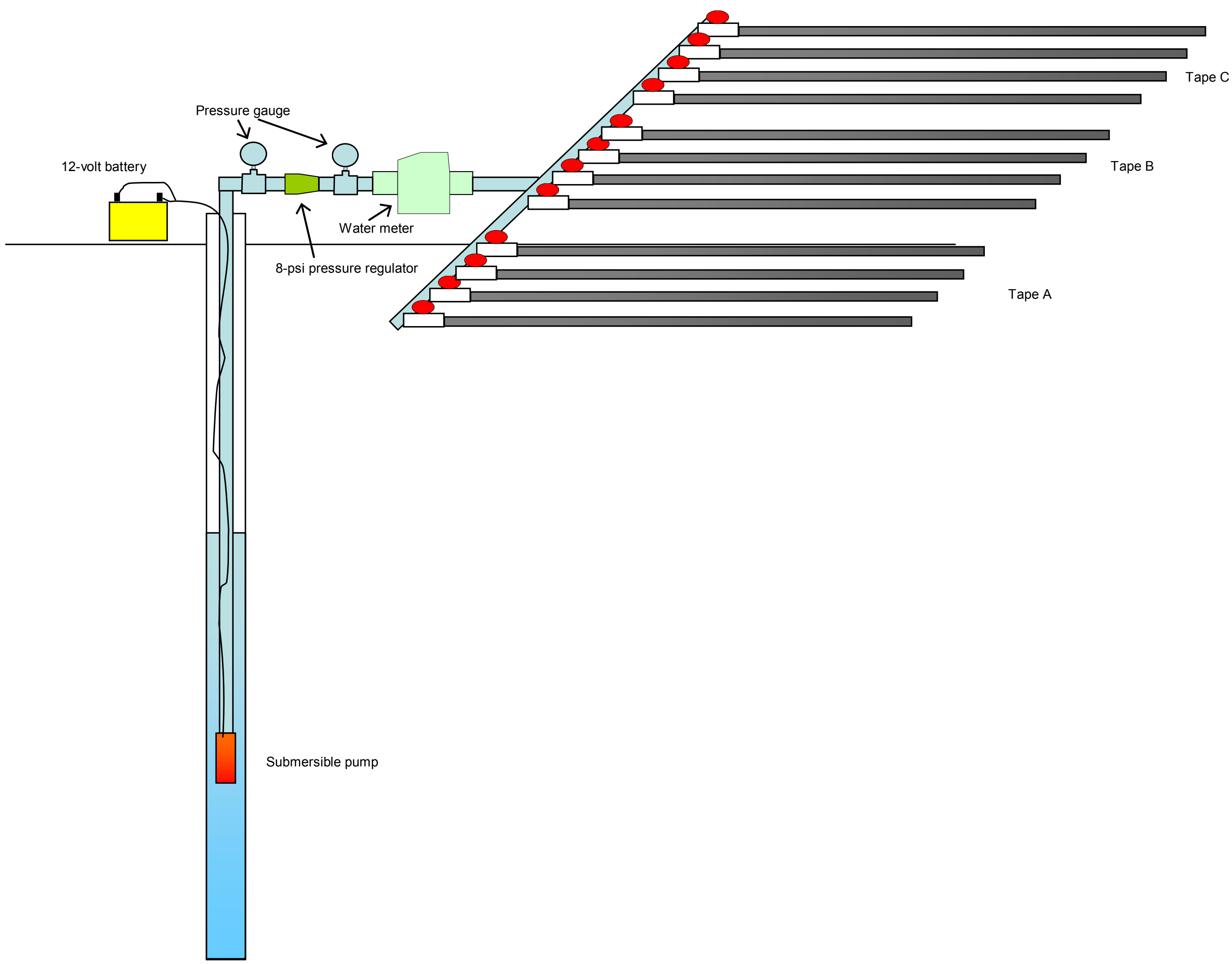

Fig. 3- A schematic of the drip system used in the test.

RESULTS

The untreated drip lines began to clog before a week had past. Eighteen days after the first irrigation water was pumped, the untreated 0.58 GPH and 0.18 GPH tapes were 73% and 50% of original flow, respectively. The treated drip lines were both at 101% of original flow. Figure 4 shows the flowrates as percentage of original flow over the course of the study. Figure 5 shows averages of both tape types for the treated and untreated treatments.

The higher flow rate (and assumed larger orifice size) 0.58 GPH tape had much less clogging then the tape with the smaller orifice sizes.

The ORP values had a reasonable correlation to ferrous iron (Fe^{+2}) values. Since ORP measures oxidation potential it would be a good "back door" method to ascertain chlorine levels. The beauty of ORP measurements are they are near instantaneous. Chlorine and iron readings require introduction of a reagent and a set reaction time. Therefore, they are somewhat impractical to use in evaluating mixing time effects. Figure 6 shows ORP values versus ferrous iron values from water samples taken from both wells.

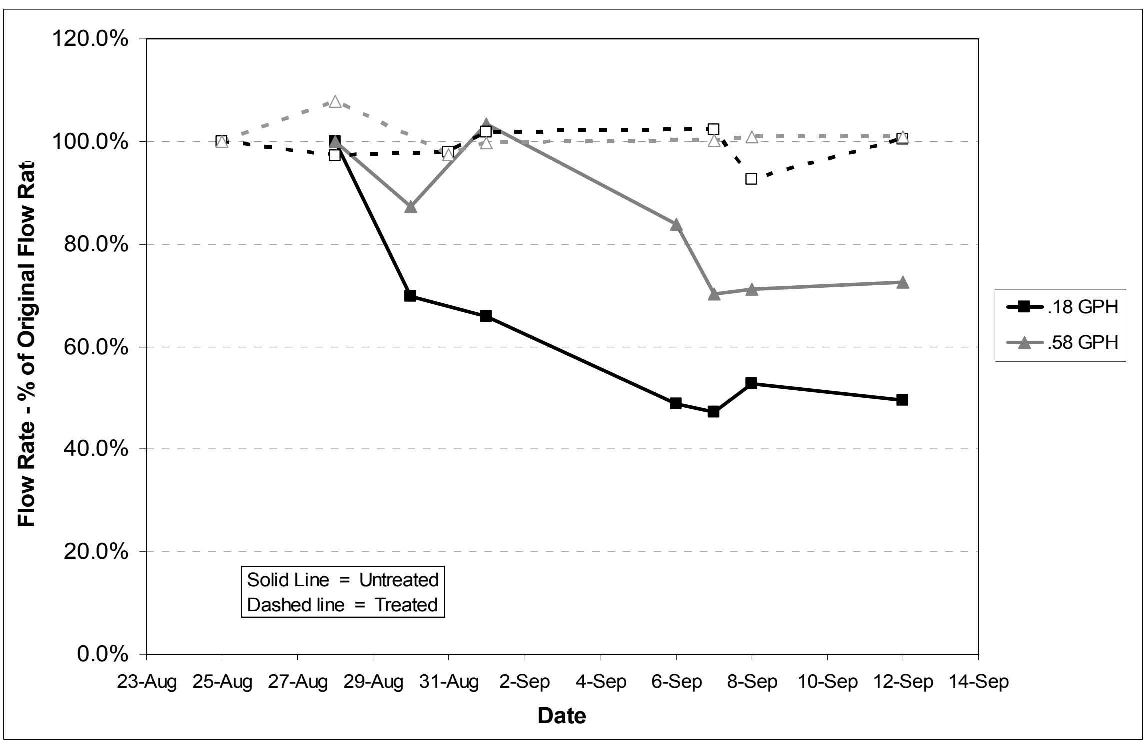

Fig. 4- Flow rates as percentage of original flow for both treated and untreated 0.18 GPH and 0.58 GPH tapes.

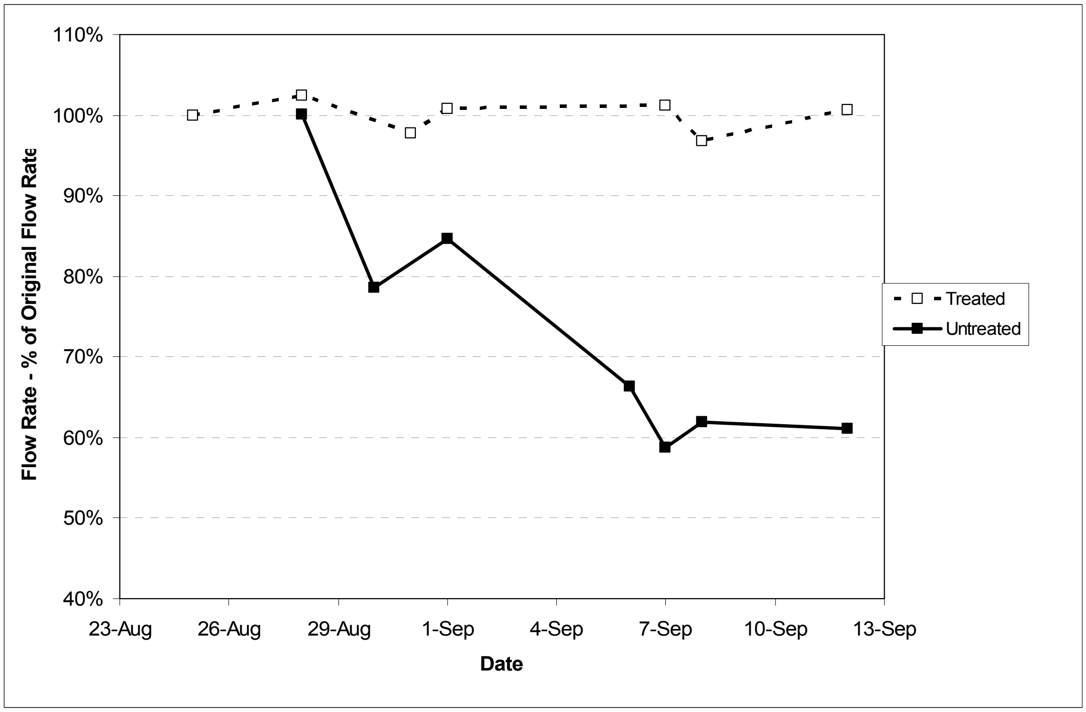

Fig. 5- The average flow rates as percentage of original flow for both tape types for the treated and untreated treatments.

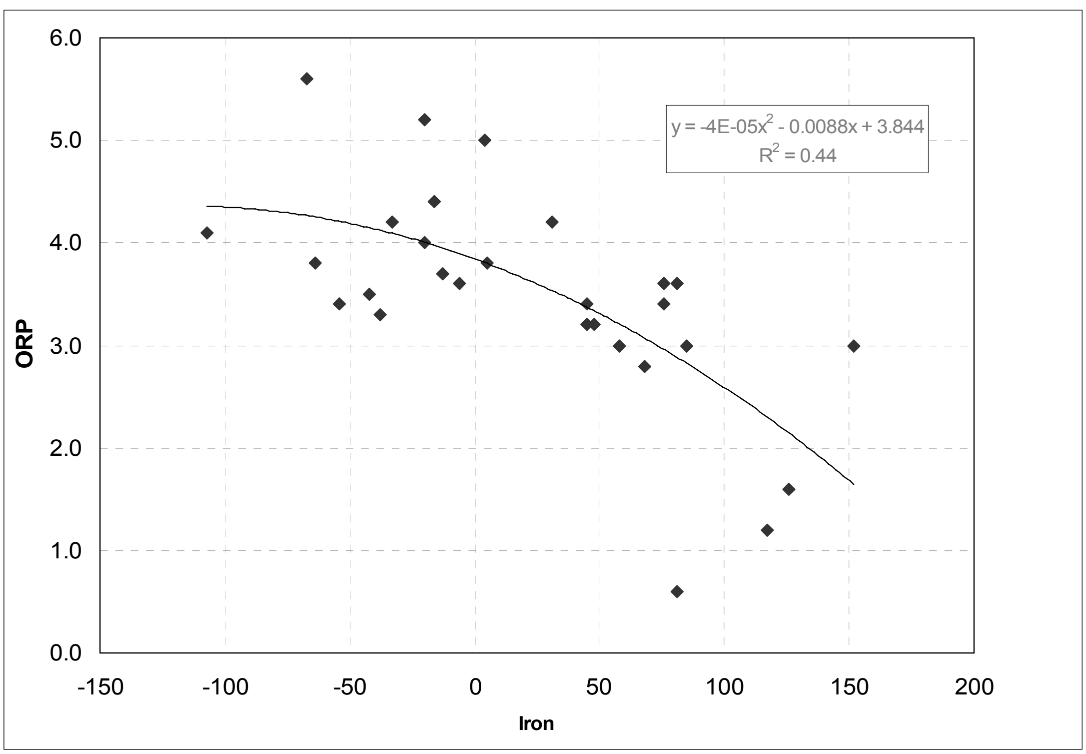

Fig. 6- ORP values versus ferrous iron values from water samples of the two wells.

CONCLUSIONS

- Super chlorination of water wells helps reducing emitter clogging in wells with high iron levels.
- Emitters with larger orifice sizes are less prone to clogging from iron related bacteria.
- Measurement of ORP may be a good tool in drip system management.

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