Ground Water Science
Science and Planning for Earth's Most Critical Resource

Well Rehabilitation Methods – Not the Same as Always

Stuart A. Smith, RG, CGWP

Many of you operate or manage water supply wellfields of two or more wells, which can be a carefree experience or an adventure. In either case, you will probably be in a position to contract well rehabilitation services at some point as well performance or water quality declines. Ground Water Science is your go-to resource for planning these occasional ventures, but we want to bring you up to date on the process first (whether you hire us or not) …

First: term check. What is "well rehabilitation"? As usually used in the Midwest region of the USA, a well rehabilitation is a series of procedures intended to improve well performance from a state of decline before the rehabilitation. Well "cleaning" is sometimes used to describe the same procedures. Other terms are "regeneration" and "restoration." A rehabilitation may include "acidizing" or some chemical additives but not necessarily. Any effective rehabilitation includes "redevelopment" – some form of mechanical agitation, often the same techniques as in well development when a well is drilled. A water supply well rehabilitation almost always finishes with a disinfection step. Note that well disinfection procedures have also been improved dramatically.

We have been involved in planning and advising on well rehabilitation for some time, including research into and application of "new wave" methods. "New wave" being since about 1985! However, we still see specifications for the "same old same old" circa 1975. Don't get me wrong, some of the "old" is as valid as ever if employed properly. But there are times to look at the new. Several relatively new well techniques benefit operations by *extending intervals between cleaning events and improve the yield of salable water.*

Next, a word on "innovative" techniques: There are STILL no miracle cures to well problems, no "silver bullets", and no final solutions, despite smooth rhetoric or sales talk. The key is to understand the strengths and weaknesses of any process and to use the best mixture in an informed manner, *along with preventive measures*. We're not going to cover all such methods in this limited space. We'll skip some with which do not have positive direct experience, and some relatively exotic treatments not in widespread use, even though they are effective. More discussion is available on our company website www.groundwaterscience.com and in Smith and Comeskey (2009).

Better Living Through Chemistry – Not Just Chlorine and Acid Anymore

Well rehabilitation is not all about chemistry, but chemistry is important.

First, it is really well past time to move past calcium hypochlorite and muriatic as the default "go-to" chemistry. Chlorine has been used to disinfect wells since the 19th Century, and it became a popular component of well rehabilitation since the end of World War II, when cheap, abundant stocks became available. However, it has become apparent in the last 30 years that shock chlorination is seldom the most effective biofouling (for example "iron bacteria") control treatment. This is because treating "iron bacteria" and other biofouling is more about removing solids than killing bacteria. Muriatic (industrial grade hydrochloric acid (HCl)) is supposed to remove the iron oxides. However, HCl tends to flash dissolve the minerals it touches first, without much penetration, if not amended by other products. This leads to the condition where a good performance recovery fades quickly. HCl is also aggressive with metal, and inhibitors not always reliable or safe to use. Some products were introduced, starting in the 1950s, to improve solids removal. Some of these choices (phosphate products in particular) have done more harm than good, but are still in the market place.

A reminder about rules: National, state and other regional jurisdictions commonly have rules for chemical use in water supply. For example, the State of Ohio Water Well Standards require chemicals used in well development to be NSF 60-listed. European nations, Australia, New Zealand and others have similar standards. Not all chemicals sold in the market for well rehabilitation are so listed. We are not so sure that standards designations are as important as regulators think they are; however, something like the NSF mark is a reliable indicator of chemical quality, if not effectiveness. *So honor your jurisdiction's rules; then you can focus on chemical purpose.*

Organic acids: No total bacterial kill is achieved with chlorine. You will never sterilize the aquifer and well system, and investigators are finding that the biofouling bacteria become accustomed to the chlorine and actually make more oxidized iron and organic byproducts. The clogging zone also simply reestablishes itself further out in the formation, beyond the reach of the treatment process. In addition, frequent use results in the formation of chlorinated organic compounds (those famous disinfection byproducts or DBPs).

Chelating organic acids such as glycolic acid have both antibacterial effects (taking apart biofilms so the microflora can be removed) and serve to remove oxidized iron products. The microflora are not extensively disrupted, but their clogging products are removed. Glycolic is highly effective against iron biofouling as well as carbonate deposits, works in carbonate water, and available in NSF-listed blends, making it a highly effective choice. It is also relatively safe to handle, even in concentrated forms.

Some organic acids, such as oxalic acid, have some advantages but also *distinct disadvantages* in certain water chemistries, such as oxalic acid in carbonate waters, forming poorly soluble oxalates.

Sulfamic acid (a dry solid) is effective against carbonate salts, and weakly effective against iron oxides. It is often used as an acid booster, or in combination with glycolic acid. *The two go together well.*

The blends: Effectiveness and safety? Most of these products are derivations or packaging for long-used and familiar chemical products such as glycolic, sulfamic, acetic, phosphoric, and citric acid, or caustic soda. Glycolic acid is paired with hydrochloric acid in one popular blend. Glycolic and sulfamic products may be combined in the well. Most blends include surfactant and dispersant polymers.

P-containing acids. Some chemicals sold for well cleaning are phosphorous-based acids (e.g., phosphoric acid). They have no particular advantage over others except for being cheaper than glycolic acid and for sulfate salt removal, where they excel. When used, P can be left behind on minerals or residual Fe or Mn hydroxides and (when oxidized to phosphate - say when chlorinating) can be a nutrient boost for regrowth. *Use a shock method of treatment to remove brittle sulfate minerals instead of using P-containing chemicals.* If you use a dishwater in lab or at home, ditch the P-containing detergents too. They help to promote algae and cyanobacterial growth in surface waters.

Polymers. There are numerous chemicals that can be used as surfactants and chelating agents in dislodging and removing clog material. One important issue is the introduction of nutrients. Ground water is typically low in P. **Do not use** phosphorus-containing compounds in well cleaning or maintenance. Other non-P polymers are used in highly effective blends, aiding the acid in taking apart and dispersing clogs. These are somewhat specific and difficult to compare.

Chlorine disinfection – the special application of well treatment. The doctrine of water well disinfection has been utterly transformed in recent years. Old way: superchlorination (more is better). New way: More like water treatment – precise calculation of (low as possible) dosage and adjustment of pH to favor bacteriocidal hypochlorous acid over alkaline hypochlorite. The pH is adjusted to < 7 (but not too low) using either dilute acetic acid (essentially vinegar) or special-purpose buffers. As in water treatment, this is easier using liquid sodium hypochlorite rather than calcium hypochlorite. Emphasis is also on cleaning the well first, *then* disinfecting, and smart placement and agitation in the well (see following).

Putting the Blended Chemicals to Work: Agitation Needed

One trouble in considering chemical treatment types individually is that they *seldom work to best advantage alone*. The problem is that practice from the 1970s onward emphasized the chemical selection and dosage, and de-emphasized the importance of time-consuming and equipment-intensive mechanical development.

Firstly, *EFFECTIVE agitation is necessary* for chemical treatments (including disinfection) to have maximal effect. The lack of effective agitation is very common and the most likely reason for poor well cleaning and disinfection results.

Figure 1. As impressive as it looks, "tank cleaning" – relying on chemistry to do the work without effective surging – does not get the job done most of the time.

Effective agitation puts chemicals in contact with clogging deposits and helps to remove them. Best common analogy: Those of you who wash dishes (and you should if you don't) know that cleaning is most effective with detergent, hot water, agitation and scrubbing.

For many situations, a highly effective and available agitation method is the century-old cable tool surge block method. The most effective version is equipped with the double surge block with airlift **(Figures 2A and 2B)**.

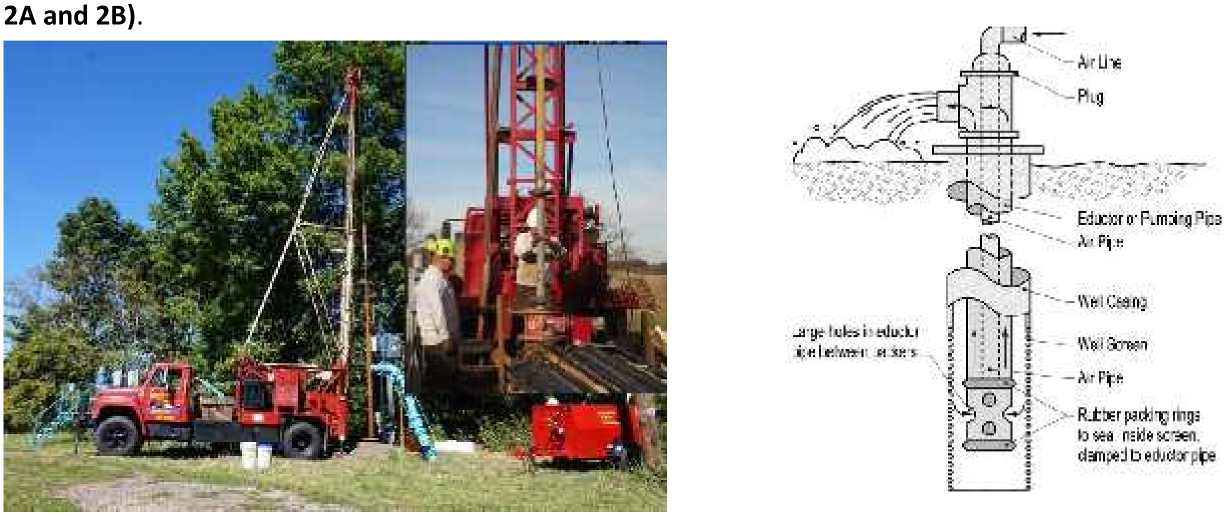

Figure 2. Cable tool systems with double surge block airlift tools. A. Above-ground systems and a view of the tool. B. A diagram of the tool in action.

The tool moves up and down, surging the water column, and airlift pumping removes loosened deposits. The tool is also very effective for introducing chemicals. When we specify *cable tool*, we mean a certain capacity for surging tool velocity, which can be provided by a mechanical cable tool drilling rig or a hydraulic system mimicking that motion, and sufficient air compressor capacity to pump and clear the water column. The design of the surge tools is also critically important, and rather specific to the well being treated. *Much improvement in results comes from simply developing longer. Longer than you think it should take. We have been adding days to our specifications on sand and gravel wells.*

Use the Force, Luke...

For wells with a long service life, in especially challenging situations, or long-neglected, the energy that cable tool surging can apply can be insufficient. Improving the application of force in redevelopment is a crucial area of improvement in well rehabilitation. The simplest first step is to improve a cable tool surging system to make it the best it can be.

Or, higher energy treatments can be employed. These mostly take the form of wire-based charge devices, fluid-percussion methods derived from seismic signaling technology, and "ultra-high pressure" sophisticated forms of water jetting. Variations and origins of these cleaning approaches have been in common use in the water and oil industry and industrial cleaning and demolition for several decades.

Wire charge devices: Among these are treatments based around detonating a shaped or charged wire, cord or device in wells (at times informally known as "det cord"). Solids disruption is effected by the detonation at differential frequencies. The water-carrying voids in the filter slits, gravel fill and the virgin soil can be significantly enlarged by this process.

Sonar-Jet® (Water Well Redevelopers, Anaheim, CA), in development for over 50 years, is a specialized form of this technology. It employs two controlled physical actions working simultaneously:

1. A mild "harmonic" (kinetic) frequency of shockwaves designed to gently loosen hardened mineral, bacterial or other type deposits, even heavy gypsum deposits almost impossible to attack chemically.

2. Pulsating, horizontally directed, gas pressure jets fluid at high velocity back and forth through screen slots to loosen deposits.

A limitation of this type of treatment is its "one shot" nature. You set the string, fire it, and retrieve it, then judge whether you need to set another cord or not.

Fluid Percussive Methods

These methods use downhole tools that generate rapid and high-energy pulses using high pressure air or other gas. Two that are available in North America use gas-impulse guns originally developed for geophysical testing (we experimented with one in 1994). These are the Airburst Method and the Airshock Method developed by Flow Industries. Layne Christensen in the USA uses a different type of design, known as Boreblast, derived from air development technology, which delivers a percussive impact. Advantages of fluid percussive methods:

1. Highly efficient action of shock wave and strong surging without utilizing explosives. The device can be fired in rapid succession, e.g., 1-ft intervals up and down a screen, and the pressure waveform and amplitude adjusted by managing the pressure and gas volume.

2. It may be used instead of or in conjunction with any chemical well treatment.

The ability to develop concussive force is an improvement in force application over air surging. The force is on the order of that developed by explosives-type tools such as Sonar-Jet, but is a) dialable and b) repeatable in the same application. This kind of force can be generated with a compact tool and the whole system is very portable.

Figure 3. Fluid percussion systems, showing a very portable compressor and reel system (Airburst) with the Airshock tool (inset).

The application is simple. The gas can be air or a specific mix, for example, nonreactive N_2 can be used. Such tools, of course, cannot bring in water if the formation is dry, nor do miracles with very tight rock aquifers.

High-Pressure Jetting: WellJet®

This method was developed in the last decade by HydroPressure Cleaning Inc. in California based on a) observation of the well cleaning state of the art as they saw it and b) comparing that to their experience with high-pressure water jet cleaning and demolition. The WellJet system, which jets with clean water at up to 20,000 lb/in^2 (psi) or ~1380 bar, also rapidly moves the tool during application, so that standard textbook limitations on jetting pressures in water well screens can be bypassed.

Experience with this system has been building with reportedly routine success. WellJet is followed by cable tool surging and airlift development to remove dislodged materials, and may also be followed by chemical application to as a secondary treatment to reduce the potential for regrowth after treatment.

Figure 4. Some views of the WellJet high pressure jetting system.

It has the advantage of focused and steerable force application and use of water instead of air, avoiding air lodging. Like the fluid percussion technologies, the system is portable and scalable to match force needs and system fragility. WellJet has been used successfully in a variety of hydrogeologic settings in the U.S. West, and in deep, difficult-to-treat wells in Jordan, where conventional redevelopment was ineffective. It has yet to be employed outside of the western region in the USA as of this writing.

Extending productive well life, the power of management

Just as conservation is powerful for saving energy, good old boring preventive maintenance gives any well rehabilitation method a better chance of success. You catch problems early through vigilance.

Well rehabilitation on the one hand and well preventive maintenance (or asset management) on the other are analogous to heart surgery and a heart-healthy lifestyle, respectively. Where the latter is neglected or half-hearted, the former often becomes inevitable. Improved well rehabilitation methods in this analogy are better surgical technique: more effective, but still invasive and takes the patient out of service. They are riskier than and a less-desirable substitute for preventive maintenance actions. Even if "rehab" is inevitable, PM methods delay it. So do good choices in design and construction. The more that invasive rehabilitation is delayed, the greater the cost benefit in terms of water pumped and paid for by customers. Frequent rehabilitation cuts into profits. Simple as that. As is the case with a human patient and heart problems, some wells are more prone to problems than others. That's nature.

Finally, good data and data trends are crucial to success both in asset management and well rehabilitation. The well monitoring, periodic step-drawdown testing, and before-and-after videos and step-drawdown testing (with hydrogeologist interpretation) should be routine groundwater utility practice, not the exception it is now. Investment in data gathering and analysis pays in more rapid and more effective response to well performance deterioration.

Conclusions and Prospects

1. Well deteriorating processes are best managed if detected at an early stage and controlled immediately. There are now available a wide range of rational, effective methods to conduct systematic preventive maintenance on wells and associated water systems to control biofouling and other problems.
2. Prevention is facilitated by effective design, construction, and operation. However,
3. There are effective rehabilitative treatments for wells that can be used to control biofouling and other well problems such as sand-pumping – some are not the "same old same old."
4. Using older and newer methods effectively improves operations and they are worth knowing and adopting.
5. While effective, both the maintenance and rehabilitation methods require knowledge to select and specify. Involving expert help working for you, the client, is a really good idea.
6. Wide application of these recently refined well rehabilitation methods will require that operators and managers of water supply and ground water remediation systems accept that improved methods will improve their operations.
7. The costs of adapting these new methods are not insignificant, but appear to be cost-effective compared to ongoing performance decline and loss of well sites or raw water capacity. If more work can be done in less time, or better results with the same time investment, and bad side-effects avoided, then these method improvements provide value.

Recommended references

Smith, S.A. and A.E. Comeskey, 2009. *Sustainable Wells: Maintenance, Problem Prevention, and Rehabilitation*, Taylor & Francis CRC Press, Boca Raton, FL. Available through this web site, NGWA, or CRC Press.

Smith, S.A., 2013. Wellfield Optimization: Metrics-Driven Operations and Maintenance in our tech article library.