# Recent Innovations in Well Rehabilitation

groundwaterscience.com/resources/tech-article-library/94-recent-innovations-in-well-rehabilitation.html

by Stuart A. Smith, MS, CGWP of Ground Water Science

 *Original version (since repeatedly updated) presented at el XV Congreso Nacional del Agua, La Plata, Argentina, April 1994.*

**Covered in this article:**

**Want details? Order our new book: *Sustainable Wells: Maintenance, Problem Prevention, and Rehabilitation* (CRC Press)**

Satisfied with this short version for now? Read on...

Numerous available text and online references (including two available through our web site) describe methods of well rehabilitation (or as it is also known: well restoration or regeneration). Much technology and methods have been improved in recent years, yet we see specifications for the "same old same old." This article describes some of those improvements and innovations.

**Innovations in well rehabilitation methods are improvements that are somewhat more effective than "conventional" methods in some cases.** Well rehabilitation or restoration and well maintenance are analogous to war and diplomacy or heart surgery and heart-healthy lifestyle, respectively. Where the latter is neglected or half-hearted (as recent history testifies), the former often becomes inevitable. Improved well rehabilitation methods in this analogy are simply the bigger, faster cannon: they make a bigger impression, but are still a poor substitute for preventing maintenance actions.

We discuss several representative development areas here. All are "innovative" in the sense of being different than the routine for many since the dawn of modern water well technology, but *all are derivative and not revolutionary*. That is in itself an important fact to know: there are STILL no miracle cures to well problems. The key is to understand the strengths and weaknesses of any process and to use the best mixture in an informed manner.

## Better Living Through Chemistry -- Not Just Chlorine and Acid Anymore

**Chlorine has been used to disinfect wells since the 19th Century, and a range of chemistry choices have been used in well cleaning since the end of World War II. Some of these choices (phosphate products for example) have done more harm than good, but are still in the market place. In recent years, the use of chlorination in wells is becoming more restrictive in parts of North America**

**and Europe (not entirely a bad thing).** Both because of this, and because shock chlorination is seldom the most effective biofouling control treatment, several other treatments are discussed briefly as follows.

**Hydrogen peroxide:** Like ozone and halogens, aqueous hydrogen peroxide is a powerful disinfectant and oxidant. It has been used with some effectiveness in removing well biofouling in both water supply and environmental wells. On the other hand, $H_2O_2$ can enhance microbial growth away from the well as it breaks down to form $H_2O$ and $O_2$. It is after all used as a means of providing oxygen in this way for in situ bioremediation of ground water. $H_2O_2$ is also *strongly reactive with combustible mixtures*. **Good use:** Removing $H_2S$ that builds up under hydrostatic pressure while HCl is dissolving iron sulfide clogs in deep wells (*don't* use chlorine for that purpose). Go on to the next...

**Brominated compounds:** Most commonly available for well use as NSF listed hypobromous acid (when aqueous - supplied in a solid form (some kind of hypobromite or -ate).**Good use:** We do not have direct experience, but good applications appear to be as a maintenance treatment. Solids like Berry Systems Inc.'s HaloSan have a longer effective shelf life than hypochlorites and dissolve better in ground water that is typically alkaline and has significant calcium hardness. Br compounds react and dissipate rather quickly, and many combined Br compounds such as bromamines are also disinfecting. We still do not recommend continuous treatment of wells with halogens unless you have no other reasonable alternative to protect your system. The bugs can adapt to these lethal conditions as well. *Also, Br and organic compounds form undesirable organobromines that potentially pose health risks.*

**Organic acids:** Contractors who perform well maintenance (as well as this author) are abandoning the use of chlorine compounds in favor of certain organic acids for use in both well cleaning and preventive maintenance treatments. You will never sterilize the aquifer and well system, and we are finding that the biofouling bacteria become accustomed to the chlorine and actually make more oxidized iron and organic byproducts. No total bacterial kill is achieved with chlorine. 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 (also brominated) organic compounds (those famous disinfection byproducts DBPs).

Chelating organic acids such as acetic or more particularly 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. Glacial acetic is somewhat less expensive per unit, but glycolic has a higher pK, can be used in lower concentration, smells better, and is available in NSF-listed blends.

**The blends: Effectiveness and safety?** Proof that well rehabilitation has become a notable market factor in North America has been the interest that companies have shown in providing products for it. There has been an appearance of numerous new products with product names. Most of these products are derivations or packaging for long-used and familiar chemical products such as glycolic, sulfamic, acetic, phosphonic, and citric acid, or caustic soda, often organic acids are paired with hydrochloric acid indicators, stabilizers, or wetting agents added.

*The fact that these products are available from suppliers that drilling companies normally frequent (instead of the back dock of the chemical supply warehouse) has made their use more attractive*. Instructions for use, provided by people who have some knowledge in the field, improves safety and confidence. Commercial support has resulted in testing and National Sanitation Foundation (NSF) certification of some products. Some states *require* "brand-name" products for some applications.

***The brand names and lack of full disclosure of blends in literature does make it more difficult to determine the formulations of the products and how they will react in use. This results in a "trust me" relationship with the supplier. Which is OK if you DO trust the supplier AND the RESULTS ARE GOOD.***

Ground Water Science will be pleased to help you through the selection process, based on the system water quality and clogging situation (nature, degree of impact, etc.).

**One trend in the USA especially, but also in Canada and Europe, has been *concern about the environmental impact of well treatment chemicals*.** Increasingly, specifications require that chemicals have National Sanitation Foundation (NSF International) or equivalent approval for potable water use, and detailed instructions on purge water treatment and disposal. It is possible that several products, notably muriatic acid (industrial-grade hydrochloric acid) with its impurities, *may disappear* from the list of suitable water well treatment chemicals in North America. This ISN'T SUCH A HEARTBREAKER considering how they are mis- and over-used by unknowledgeable people. Good quality HCl, with its high H+ Cl-ionization constant, will likely remain in wide use (there isn't a good chemical alternative for Fe sulfide removal -- although shock treatments work well). Glycolic acid, with its own high pK and NSF certification in many blends, is a safer, more versatile alternative for most other choices, but itself is blended with glycolic acid in at least one popular and effective mix.

The carbon dioxide treatments bill themselves as “greener” and permitting well cleaning without chemicals. However, glycolic treatments, properly designed and administered, are at least as safe, even around sensitive electrical equipment, and certainly effective in most cases. **The trick is in the application – which we can train you to do**.

**P-containing acids.** Some chemicals sold for well cleaning are phosphorous-based acids (e.g., phosphoric or phosphonic). They have no particular advantage over others except for sulfate salt removal, where they excel. When used, P is 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. Those who promote these products versus acetic or glycolic acid note that the latter types can leave behind short-chain carbon compounds as food (e.g., acetate). Our experience is that ground water already has a significant assimilable C content, but it lacks the all-important P needed for respiration and energy transfer in cells. Also, dislodged biofilm supplies large quantities of assimilable C. We advise taking your chances with the carbon. 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 promote algae and cyanobacterial growth in our 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.

***Use of heat:*** This approach is described in a variety of the “classic” 1990s well rehabilitation literature and in literature available at the Droycon Bioconcepts website. Heat is often favored as a biofouling removal method where chemicals cannot be used for environmental reasons. However, heat is cumulative around the well structure when applied (due to lithologic resistance to heat transfer – same problem as with cold), and can actually enhance growth away from the thermal shock zone. It can also congeal biomass around the treated area -- sort of like cooking an egg. Alford and Cullimore (1999) provide a useful experience history. Using heat alone is also very inefficient in terms of fuel or power to generate thermal energy, and can also deteriorate grout, plastic casings, and other bore features. We have found through experience that the best approach to using heat is as a part of the blended chemical heat treatment method described in the following.

## Blended Method Treatments

**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) mechanical development.

**(1) Firstly, *EFFECTIVE agitation is necessary* for chemical treatments to have maximal effect.** The lack of effective agitation is very common and the most likely reason for poor well cleaning results. We struggle constantly to get folks to bring effective systems to the well site.

**(2) Chemical *activities can be otherwise augmented* by mixtures and temperature increase.**
For example, surfactants improve the contact between disinfectants and bacteria in biofilms, acids provide ionic shock, and such *mixtures can be heated* to increase molecular activity. An extended contact time additionally improves effectiveness of biocidal action. 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, and agitation and scrubbing.

**The patented BCHT process (developed by ARCC Inc., Port Orange, FL, USA, U.S. Pat. # 4,765,410) is probably the best example of an *intentional blended method approach*.** Its effectiveness and results have been studied by the U.S. Army Corps of Engineers on an unprecedented scale for a rehabilitation method. It is the best-documented innovative method (Leach et al. 1991; Kissane and Leach, 1993; Alford and Cullimore, 1999; Ground Water Science, 2000; Guy et al., 2006). *

* Contact Ground Water Science for a reference list, or see our *Sustainable Wells* text (2009, CRC Press).

**This method employs all the recommendations for rehabilitative treatment based on recent research:**

1. Analysis of problem causes
2. Physical agitation in combination with chemicals
3. Heat augmentation of chemicals
4. Appropriate mixtures of chemicals customized for the situation
5. Staged treatment to produce various effects.

*The treatment is followed by analyses of results and treatment is repeated and modified as necessary*. The BCHT process involves three phases of application to *shock, disrupt, and disperse* biofouling.

**The *Shock* phase** involves water-jet injection of a heated (90-200 F) tailored chemical solution (chlorine-based early in development, now more typically high-quality glycolic acid but sometimes pH flip-flop) amended with *nonphosphate* (polyelectrolyte) surfactant (known as CB-4 – works well against calcite) into the production zone. Using commercial blends can replace these “a la carte” choices. The result is (1) a reduction of chemical demand in the Disruption phase (next), (2) softening of biofouling and encrustants, and (3) increasing microbial kill and more effective development.

**The *Disruption* phase** is commenced after an overnight "presoak" involves more customization (based on analysis of the well conditions), but revolves around injecting with water-jet a tailored chemical mixture, again heated to achieve 60 to 95 C in the well and allowing a contact time as long as possible. The pH shift is down to as low as pH 1 (but more typically pH 2). Heating increases metabolic rates at the fringe of the heat influence zone, increasing assimilation of toxic disinfectants.

**The *Dispersion* phase** involves "plain good old fashioned well development": the physical removal of the disrupted fouling material from the affected well surfaces. Standard surging methods are employed.

**BCHT has been employed on a variety of applications, including municipal water supply wells, pressure-relief wells with redwood-stave screens, and pumping wells at dangerous hazardous waste remediation sites. *The process requires very specific knowledge of chemicals, their application, and their effects on fouling, wells, and ground water quality. With the passing of George Alford in 2009, (we miss him) his company ARCC Inc. is not directly providing the BCHT service. However, GEO Consultants LLC , Kevil, KY is providing the service. If others do so, let us know.***

### Use the Force, Luke...

**Improving the application of force in redevelopment is a crucial area of improvement. These mostly take the form of wire-based charge devices, fluid-percussion methods derived from seismic signaling technology, fluid oscillators, 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. These methods take advantage of the different elastic properties of the materials (filter pipes, gravel back-fill and surroundings, deposits between the gravel particles) to loosen deposits from well and aquifer/filter pack surfaces.

**Wire charge devices:** Among these are treatments based around detonating a shaped or charged wire, cord or device in wells. These are 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, Pat. #4,757,663**), in development for over 50 years, is among the best known of these. 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 the perforations to deep clean the productive aquifers.

The shock waves loosen crust-like deposits and the gas jets repetitively surge the well's own fluid back and forth through the perforations, to deep clean the surrounding aquifer.

**EnerJet (Welenco, Bakersfield, CA)** is a similar device (explosive/implosive type of cleaning method) that involves the use of detonating cord and blasting caps attached to a wire carrier that is used to clean wells. Different strengths or grain sizes of detonating cord are used depending on the diameter, condition, and amount of encrustation on the casing. There is a centralizer at the top and bottom of the string, plus a basket at the bottom to catch a sample of the encrustation and gravel that may enter the well during the cleaning process. The high-energy gas breaks up encrustation as it moves through the perforations and into the gravel pack and formation. According to the developers, EnerJet works better on hard mineral deposits than on "bacteria or algae"; "they seem to absorb the blast and are often treated with chemicals."

**Sometimes problems identified as biofouling actually have hydraulic impact through deposition of hard solids in pore spaces, especially around persistently dewatered screens and filter packs. We have had very good results using it in such wells, and in rock wells with hardened ferrous sulfide encrustation.**

**A highly effective use of the system is as follows:**

1. Conduct borehole TV and review history and water chemistry, and determine that a hardened or entrenched deposit exists
2. Perform an initial bore cleaning
3. Perform the wire charge treatment
4. Follow immediately with a chemical (optional) and redevelopment (mandatory) step
5. TV, pump test and review.

***The Shockblasting Method:*** **The Shockblasting® method is marketed by Berliner Wasserbetriebe (BWB),** and shows howthese methods arise independently around the world. Andreas Wicklein of BWB notes that "This method has been further developed, so that a regeneration of wells made of brittle or worn-out materials can be carried out. Before, these wells would have been unsuitable for regeneration using the Shockblasting® method (i.e. vitreous clay, plastic and similar materials, as well as strongly corroded steel filters). Now, a better quality filter pipe (coiled wire filter), which is somewhat smaller, is used. The old filter is detonated along with its pipe. For this, a suitable explosive charge is used, thus loosening and regenerating the surrounding filter gravel. In this case as well, an intensive de-silting is carried out afterwards in order to improve the results even further."

### 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 are the Airburst Method*, pulse generated by a Bolt Technologies gas gun, and the Airshock Method developed by Flow Industries, using a series of gas impulse guns of their own design. The Airshock method is also available for use by well service contractors worldwide (including the USA). Layne Christensen in the USA at one time offered this methods under the Boreblast II service mark but now uses its original Boreblast (modified air development) technology. A third supplier is THM GmbH, Markkleeburg, Germany. This one apparently also uses water or other fluids. Advantages:**

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. Very effective for well development, redevelopment, routine well maintenance and post-treatment well surging or airlifting.
3. It may be used instead or in conjunction with any chemical well O&M technique.

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. The application is simple. These are major advantages. See the videos linked from the Flow Industries Airshock link. The Airshock tool comes in a wide range of sizes, one of which is small enough and suitable for redeveloping two inch diameter wells. 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, or do miracles with very tight rock aquifers.

**Case histories that objectively show "proof of concept" are still hard for the public to come by (although hundreds of treatments have been conducted). Some that we have (not publishable) are quite encouraging, showing objective improvement in well specific capacity (that is, improvement at the same or higher flow rates) in both screened and rock wells.**

**Oscillating Fluid Tool: Downhole Fluidics Inc.** at one time marketed an oscillating fluid tool that works by setting up a 200-Hz harmonic as water flows through the tool head. This vibrates solids loose from formation and well surfaces. However, their web address has gone back to Go Daddy.

**WellJet®. This method was recently developed 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 water at up to 20,000 lb/in² (psi) or 1379 bar also rapidly moves the tool during application, so that standard limitations on jetting pressures in water well screens can be bypassed. Experience with this system has been building with apparently routine success. Ground Water Science does have some experience with this system in Jordan, but we have not directly performed pumping tests or collected many data from treatments. WellJet is followed by cable tool surging and airlift development (sometimes more recently their modification known as the Worm) 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.

It has the advantage of focused and steerable force application, use of water instead of air, with associated air lodging. The system appears to be portable and scalable to match force needs and system fragility, and application in systems such as drains in addition to wells. At present, distribution of the service is limited. The WellJet team is adding case history information on their website and experience in general on a regular basis. **Look for much more from this group.**

### $CO_2$ injection: Aqua-Freed and Aqua Gard

*Aqua-FreedTM process: cold CO2 fracture opening and encrustation removal (often called "freezing")*

While "dry ice" (solid CO2) has long been used as a well development tool in North America, control of dose and application have been a problem. The Aqua-Freed procedure (Aqua Freed, a subsidiary of Subsurface Technologies Inc., Rock Tavern, NY, described in Mansuy, 1999) was developed as a way to provide the redevelopment effects of cryogenic CO2 in a controlled manner. Post-planning, this process has four steps as follows:

1. Injection of gaseous CO2 to begin forming carbonic acid
2. Injection of cryogenic liquid CO2, starting agitation and freezing
3. Allowing time for penetration into the formation and reaction
4. After application, remove packer and thaw, venting and depressurization
5. Mechanical redevelopment (this is crucial, Mansuy 1999* notes)

This process is described by its developers as acting on the formation and encrustants in the wells through gas expansion and freezing and thawing, which dislodges deposits, and also through the formation of carbonic acid, acting under pressure. The carbonic acid solution is relatively high in concentration and acts as a mild acid, which can attack deposits. The thermal shock on bacteria and their biofilm networks probably has some benefit in dislodging biofouling.

***The Aqua-Freed process has some other attractive features:***

1. The injectant is chemically reduced and not reactive with organic molecules
2. It does not work under high pressure, so that fracture opening is minimized

3. The material, compressed $CO_2$, is relatively safe to handle (suspending dusts of aluminum, Mg, Ti, Cr and Mn in $CO_2$ streams should be avoided)
4. No other chemicals are absolutely necessary. Some Aqua-Freed service providers will add a chemical rehabilitation step and additional redevelopment at this point as needed. This is highly recommended.

**Problems identified are (at present):**

1. Commercial restriction (exclusive territories) and not cost of the action may result in a lack of optimal price (Subsurface Technologies does not agree with this assessment – “we report, you decide”). Some price differential between an Aqua-Freed quote and a "standard" chemical rehab quote may be due to inadequate chemical application or handling and disposal. Some contractors will "low ball" chemical treatment bids, betting on change orders later. This is something you should definitely be aware of. In other words "compare apples to apples" in proposal review.
2. Possible structural damage to the well (also disputed, but service providers have told stories – probably a declining situation as they gain experience). This is not significantly addressed in Mansuy (1999).
3. The cold thermal shock is admittedly not nearly as effective as can be applied by heating the water.
4. Kinetic force generated is readily dissipated in hydraulically highly conductive aquifers and is most likely confined to discrete channels. In other words, your author is agnostic about their description of what goes on during treated, and especially the illustrations of it.
5. The poor thermal conductivity of lithological materials also will limit cold transmission to the immediate area of the well, based on studies of glacially influenced materials.
6. In our experience: Competence in application is not consistently high quality. If packers are not set properly and the $CO_2$ blows out up the casing, the effort and money are wasted.

***Its best use is probably in situations with significant encrustation immediately at the screen or borehole wall vicinity, removal of which will provide significant relief. ALSO, where chemicals are (irrationally) forbidden.***

Casings must be firmly sealed into the formation with cement, unless the packer is used to isolate the casing. In its current form: it is probably best to be very cautious with bentonite-grouted wells, especially structurally weak monitoring wells (although with time, use with these wells should be possible). One additional problem at present in recommending the process is a lack of DETAILED *objective,* documented case histories of its effectiveness (short testimonies are available at their web site). This situation WAS NOT alleviated with Mr. Mansuy's 1999 book or more recent publications. The 2006 AWWA Research Foundation (now Water Research Foundation) report on well cleaning comparisons includes a number of Aquafreed case history evaluations.  The original schedule for release of this report was 2000 and finally published for restricted distribution in 2006. In this report, the documented Aquafreed cases included additional cleaning steps (chemical and mechanical), such that it is not objectively possible to separate the effect of the Aquafreed treatment from that of the additional treatment steps. So the question of Aquafreed effectiveness is still open.

**Your authors do not have direct experience with this procedure and cannot vouch for its effectiveness.** We are willing to be available to so document results if a service provider or well owner would like us to do so.

**The carbon dioxide injection maintenance technology (Aqua Gard) marketed by Subsurface Technologies** appears to have considerable merit, as a $CO_2$ saturation environment in well water discourages microbial growth and reduced state discourages oxidation, and the CO2 injected generates some development energy.

### Suction flow control

**In any well, the pump represents the lowest pressure point in the aquifer volume affected by the well.** Where the pump is situated in the casing above the screen, almost all flow enters through the top 10 to 15 % of the screen (Nuzman, 1989; Pelzer and Smith, 1990; Ehrhardt and Pelzer, 1992). If the pump is situated in the screen, flow through the screen occurs predominently near the pump. Inflow velocity is higher than the average calculated for a screen dimension and slot size, using, for example, the methods published in Driscoll (1986). A concentration of clogging is commonly induced in this high-velocity zone during well operation. Additionally, German experiments (Ehrhardt and Pelzer, 1992) have demonstrated a vertical flow component in some filter-packed wells due to this flow pattern. The relatively high-velocity vertical flow tends to erode filter pack and results in sand pumping.

**One technology that has been developed in recent years to counteract uneven well inflow is the refinement of the controlled-inflow pump tailpipe referred to as a suction flow control device (SFCD) or engineered tail pipe.** SFCD are simple devices that are refinements of the field- or shop-fabricated perforated pump intake pipes also installed to modify the path of water entering the pump. SFCD, like tailpipes, may be installed attached to the pump intake, or installed as a liner in the well intake, sealed by a packer at the top of the screen. Actually, with the right calculations and good fabrication, engineered tail pipes can potentially match manufactured SFCD.

**The SFCD refinement is that perforations are made in an engineered pattern that forces flow to enter the well in a more cylindrical fashion as intended, generally by gradually reducing resistance to flow from top to bottom**. The perforation pattern is designed based on well hydraulics information for the specific well: screen length and diameter, slot size, total depth, depth-to-screen, and design pumping capacity. Units installed in North America, Europe, and the Mediterranean region have a generally excellent track record of controlling sand pumping even in flawed and damaged wells with very little hydraulic resistance.

**A proposed use for SFCD in pumping wells is to normalize flow across the intake screen, reducing the tendency of clogs to concentrate near the pump, and thus lengthening the time between well cleaning events.** Secondarily, SFCD can reduce the negative impact of less-than perfect design and installation in formations with finely laminated fine-particle layers. The use of the specifically designed SFCD, as opposed to crudely engineered imitations, is recommended for better results.

**The SFCD design available and fabricated in the U.S. is the Aquastream, produced by Sand Control Technologies (Aquastream Inc.).** Aquastreams consist of a single-wall PVC or stainless steel pipe, which is slotted in the pattern desired, coated with an external filter pack. While the design and fabrication of the Aquastream product resulted in mixed success in the past, recent experience has offered a record of good service, according to Aquastream. The company offers a guarantee, continues technological advance, and offers related services to improve the prospects of success with their technology.

**A more refined design and fabrication process was developed by Rudolph Pelzer of Herzogenrath, Germany. This design has been marketed under the Eucastream mark, first by Kabelwerk Eupen, Eupen, Belgium, and then Eufor Inter SPRL (also Eupen, Belgium) in Europe and the Mediterranean region.** The Eucastream consists of a single, specifically perforated PVC or stainless steel pipe without a filter pack that, like the Aquastream, fits with a seal inside the well intake. Unfortunately, most practical commercial access to this design is still limited to Europe and the Mediterranean, although we have found them installed in the USA. It is possible to find published calculations for an engineered tail pipe that serves the same function.

### Well gizmos and gadgets

***Improved materials:*** Slowing deterioration of well components and limiting recurrence of preventable problems is making the success of rehabilitation more likely. Notable product developments include the widespread availability of all-stainless steel and stainless-and-plastic pumps, high-quality rigid plastic pump discharge (drop) pipe with twist-on-twist-off connections (e.g., Certa-LokTM ), and flexible discharge hose that permits easy pump service while providing reliable, high-strength, corrosion-resistant material (e.g., WellmasterTM by Kidde Fire Fighting, Angus Fire, North America or Boreline Inc., Hose Solutions, Inc.).

***Computers and controllers:*** SCADA systems originally developed for process treatment have been adapted for wellfields, permitting rapid, easy, and continuous monitoring of well and pump hydraulic performance, and even physical-chemical changes. These have become flexible and inexpensive enough for nearly all important wellfields. Pump controllers help to maintain regular current flow of the proper characteristics and phase to pump motors, prolonging motor life, and shielding motors from line surges. All pump motors should be equipped with automatic controllers.

## Conclusions and Prospects

There are now available rational, effective methods to conduct systematic preventive maintenance on wells and associated water systems to control biofouling and other problems.

1. Biofouling can only be effectively prevented if detected at an early stage and controlled immediately, and other well clogging problem prevention benefits from early detection.
2. There are effective preventive and rehabilitative treatments for wells that can be used to control biofouling and other well problems such as sand-pumping. However,
3. Some devices available that can help in preventing deterioration have limited commercial availability at the present time. Demand has to be developed.
4. While effective, both the maintenance and rehabilitation methods require knowledge. Personnel must be trained in the use of these methods, and implementation may require some expert guidance.

**Wide application of these recently refined methods will require that operators and managers of water supply and ground water remediation systems accept that improved methods will improve their operations. Also, education and specific training are required.**

***The costs of adapting these new methods are not insignificant, but are absolutely less costly than the effects of uncontrolled deterioration of wells and water systems. Besides, these costs become budgeted, regular maintenance costs rather than emergency costs. Companies that provide services for wells may find profitable new opportunities.***

**We highly recommend that troubleshooting well problems and making plans for solving them be done by competent, experienced professionals, and that you obtain several opinions or get them from relatively unbiased sources. We endeavor to be that commercially unbiased expert resource.**