**Well Rehabilitation**

**Well Rehabilitation is defined as restoring a well to its most efficient condition by various treatments or reconstruction methods (*Groundwater and Wells*). This lesson will examine the causes of deteriorating well performance and methods, both traditional and of more recent introduction, of addressing this area.**

**Poor and deteriorating well performance is the result of numerous things. Causes may include inherent characteristics of the aquifer which supplies water to the well, the well design, its construction, water quality and other environmental factors, and even the operation of the well.**

**To determine any loss in performance, some reference point is needed. Performance standards are established by conducting a pumping test as part of the completion of every new well. The pumping test results allow the well owner and the rehabilitation contractor to monitor the performance of the well to detect any drop in yield. Ideally, the well owner needs to be aware of the following characteristics of his/her well:**

- **Static water level**
- **Pumping rate**
- **Pumping water level**
- **Specific capacity of the well taken at a benchmark pumping rate**
- **Sand content of a well water sample taken at the required pumping rate**
- **Total well depth**
- **Impact of nearby wells**

**Well rehabilitation is the necessary required action when a well has deteriorated beyond the point when maintenance programs will resolve the decrease in yield or when sand pumping reaches unacceptable levels. If rehabilitation cannot restore the water quality and water quantity to acceptable levels the final step has been reached, well abandonment and new well construction will be required.**

**Any study on well rehabilitation would be remiss not to mention well maintenance. It is widely accepted, that preventive maintenance costs are 10-20% of the costs of hiring a well rehabilitation specialist; and that the cost to rehabilitate a well is also 10-20% of the costs of new well construction. Since this is the case, the time and attention paid to ongoing well maintenance is a wise investment and always the most prudent course of action.**

**In addition, one must keep in mind that if the wells performance has declined by 25%, it is time to begin rehabilitation efforts. In well maintenance and in rehabilitation, as in many areas of life, 'an ounce of prevention is worth a pound of cure' so always the best procedure.**

**Maximizing well life and productivity begins with well design prior to construction. Some causes of poor well performance are preventable during the design and construction phase if properly addressed. These include:**

1. **Poor site selection or poor selection of the specific water bearing**

2. **Poor design of the well intake area.**
3. **Poor selection of the casing material - strength or corresion resistance**
4. **Poor well construction**
5. **Poor well development**

**The above showcase the significance of choosing a contractor whose knowledge of the area and reputation will give the well owner some assurance that the above five areas of possible issues will be addressed.**
**The table below identifies the most typical well problems that occur in the aquifer types listed. The typical maintenance frequency used by municipal well owners for addressing the problems. is also identified.**

| Aquifer Type | Most Prevalent Well Problems* | Major Maintenance Frequency Requirement (Municipal) |
|---|---|---|
| Alluvial | Silt, clay, sand intrusion; iron precipitation; incrustation of screens; biologic fouling; limited recharge; casing failure | 2-5 years |
| Sandstone | Fissure plugging; casing failure; sand production; corrosion | 6-10 years |
| Limestone | Fissure plugging by clay, silt, and carbonate scale | 6-12 years |
| Basaltic lavas | Fissure and vesicle plugging by clay and silt; some scale deposition | 6-12 years |
| Interbedded sandstone and shale | Low initial yields; plugging of aquifer by clay and silt; fissure plugging; limited recharge; casing failure | 4-7 years |
| Metamorphic | Low initial yield; fissure plugging by silt and clay; mineralization of fissures | 12-15 years |
| Consolidated sedimentary | Fissure plugging by iron and other minerals; low to medium initial yield | 6-8 years |
| Semiconsolidated and consolidated sedimentary | Clay, silt, sand intrusion; incrustation of screens in sand and gravel wells; fissure plugging of limestone aquifers in the interbedded sand, gravel, marl, clay, silt formations; biologic fouling; iron precipitation | 5-8 years |

**To strengthen what is included in the above table, but without specifying types of aquifers, the causes of poor well performance include:**

## Causes of poor well performance

There are numerous causes of poor and deteriorating well performance. Causes may include inherent characteristics of the aquifer which supplies water to the well, the well design, its construction, water quality and other environmental factors, and even the operation of the well.

### Definitions of poor well performance and causes

**Pumping water level decline:**

**Causes:** Outside influences, such as regional water level declines or well interference, or reduced hydraulic efficiency in the well, resulting from plugging or encrustation of the borehole, screen, or gravel pack, or plugging of a gravel pack by sand, silt or clay.

**Lower specific capacity:**

**Causes:** May be those that lower pumping water level (PWL) or that reduce yield, or both, including encrustation, formation plugging, corrosion and biofouling. Both pump and the well/aquifer system may be involved.

**Lower (or insufficient) yield:**

**Causes:** Dewatering or caving in of a major feature or other water-bearing zone, insufficient development, lack of connection to water-bearing fractures, pump wear or impeller detachment from shaft, encrustation, plugging, or corrosion and perforation of column pipe, increased total dynamic head (TDH) in water delivery system.

**Complete loss of production:**

**Causes:** Generally a catastrophic loss of well production due to dewatering, plugging or collapse. Also pump failure. Multiple cases. Usually preceeded by noticeable well performance decline. Complete failure usually indicates negligence in design, construction or operation.

**Sand/silt pumping:**

**Causes:** Presence of sand or silt in fractures intercepted by well completed open-hole, leakage around casing bottom, inadequate screen and filter-pack selection or installation, screen corrosion, collapse of filter pack due to excessive vertical velocity and wash-out.

**Silt/clay infiltration:**

**Causes:** Generally inadequate seal around the well casing or casing bottom, infiltration through filter pack, or "mud seams" in rock. Generally material too fine to adequately screen or otherwise remove in the well.

**Chemical encrustation:**

**Causes:** Groundwater chemically tending to settle dissolved solids, usually high Ca, Mg carbonate and sulfate salts or iron oxides, aggravated by high near-well turbulence and velocity, oxygen entrainment due to excessive drawdown, microbial oxidation. Causes reduced specific capacity and efficiency.

**Biofouling plugging:**

**Causes:** Microbial oxidation and precipitation of Fe, Mn, and S, with associated growth and slime production. Usually associated with simultaneous chemical encrustation and corrosion. Associated problem: water quality degradation. Includes, but not always, "iron bacteria". Causes reduced specific capacity and efficiency, reduced yield, and even complete well production loss.

**Pump/well corrosion:**

**Causes:** Natural aggressive water quality, including $H_2S$, biofouling and electrolysis due to stray currents. Aggravated by poor material selection in pump or column pipe, casing and screen. May result in sand pumping, poor water quality, and structural collapse.

**Well structural failure:**

**Causes:** Tectonic ground shifting, ground subsidence, failure of unsupported casing in caves or due to poor grout support, casing or screen corrosion and collapse, casing insufficient for in-ground conditions, collapse of unstable rock borehole.

Related problems include poor water quality, pump wear, and pump corrosion.

**There are 4 routinely encountered causes of decreased well performance or even total well failure:**

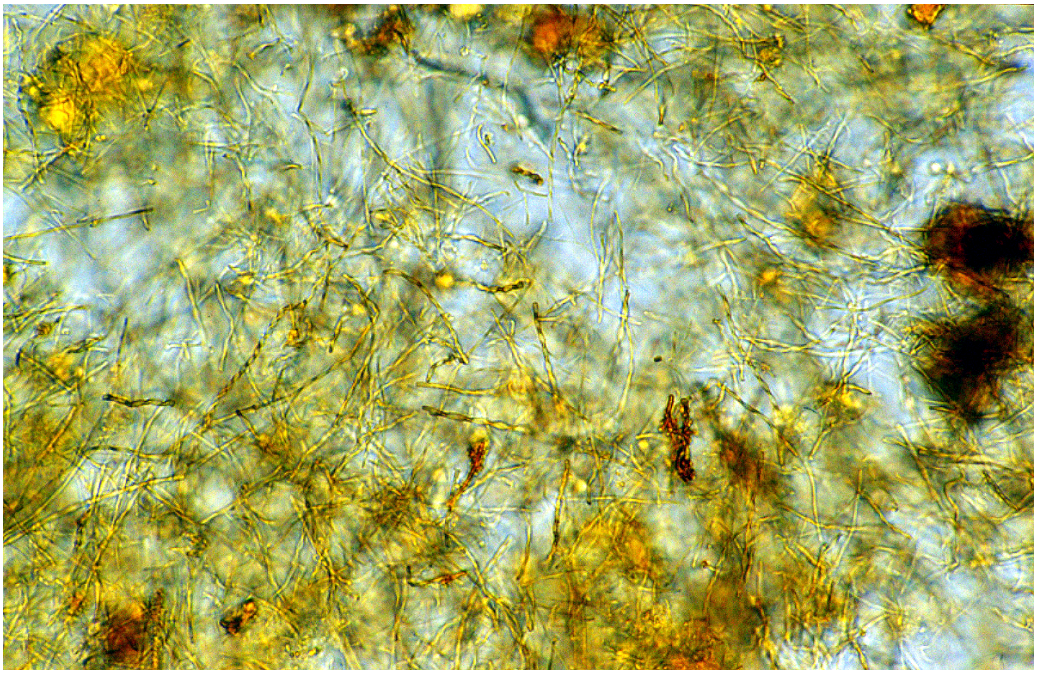
1. **Incrustation**
2. **Biofouling**
3. **Physical Plugging of the Formation and/or Screen**
4. **Corrosion**

1. **Incrustation- A major cause of well failure, incrustation is caused by the settling out of dissolved minerals and their compounds from the groundwater. The settling out is accelerated by the turbulence and high velocity of the groundwater as it enters the near-well area during pumping. Incrustation is often found together with biofouling, discussed below.**

**Scale (incrustation) can take several forms. It may form a hard, brittle, cement like deposit or it may be a soft, paste-like sludge under different conditions.**

**2. Biofouling- The clogging of a water well by communities of natural organisms which create slime deposits in and around the well. These slime deposits are the natural result of the accumulation of living and dead bacteria, their sheaths, stalks, secretions and other leavings, and their reactions with dissolved minerals in the wellwater. While generally all biofouling bacteria are called "iron bacteria" other bacteria may also be involved.**

**How do these microorganisms affect the water? In addition to health-related problems, bacteria and other microorganisms may affect water quality and contribute to clogging, corrosion, and changes in water treatment performance, as well as unpleasant taste and odor.**

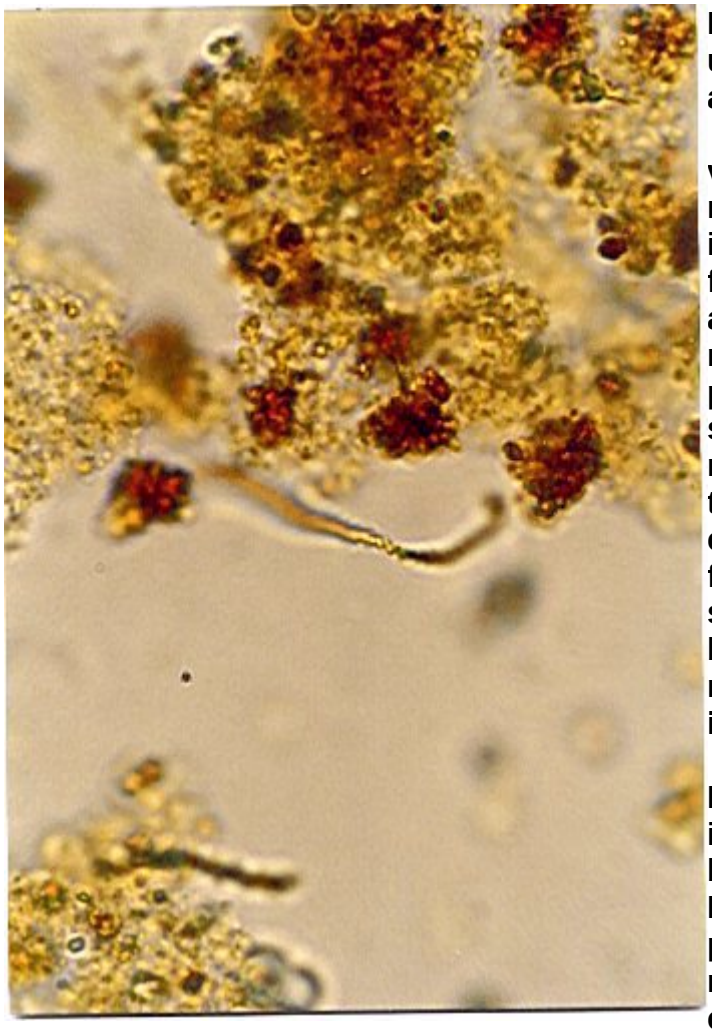


***What is the "iron bacteria" problem?***

**Better described as *iron biofouling*, the problem popularly known as "iron bacteria" is both complex and widespread. It is a natural phenomenon - microorganisms interacting with metals and minerals in their environments. Iron biofouling affects wells and water systems around the world in all sorts of aquifer environments: contaminated and pristine and climates arctic to tropical. In some places it causes great damage, in others it is considered a minor nuisance.**

**Iron bacteria is one type of biofouling among several, including the characteristic white sulfur slime of sulfur springs. *Manganese*, and even *aluminum* biofouling is also found in ground water systems.**

**Iron and other biofouling consist of biofilms which include living and dead bacteria, their sheaths, stalks, secretions and other leavings, and embedded metal oxihydroxide particles.**



**Bacterial iron can usually (but not always) be distinguishable visually from purely mineral iron incrustation by its soft, feathery or slimy appearance, and microscopically by the presence of bacterial structures and distinct mineral types. Under the microscope you can see the long, thin filaments or twisting stalks of various types by which microbiologists name the iron bacteria.**

**Iron particles are often incrusted on the bacterial structures. However, the bacteria present consist of many types, and the classy looking filaments and stalks in the textbooks may be entirely absent. *These biofilms are natural and usually harmless*. Natural iron biofouling often acts as a preliminary iron filter in wells and therefore can serve a *positive* function as well.**

**Biofouling can be a nuisance. <u>Mineral iron encrustation without the involvement of bacteria is rare in normal ground water environments. Generally, iron biofouling is the cause of iron build up in wells and pipes.</u>**

**<u>Bacterial iron may *build up quickly* compared to mineral incrustation.</u> In addition to causing problems in wells, the bacteria may colonize tanks and water treatment devices, as well as spring outfalls.**

**Iron biofouling generally causes side effects such as slight and intermittent sulfide odor, breakthroughs of red water, and pitting-type corrosion of iron and steel.**

***The causes of bacterial iron buildup include the following:***

**The root causes of bacterial iron buildup is the presence of the bacteria itself, dissolved or complexed iron or (sometimes) manganese or sulfur**

**species, and an environment that encourages bacterial survival and growth.**

**Factors that may cause natural iron biofouling to be worse than it might be otherwise include: inappropriate well, filter or plumbing design or material choice, or construction, poor choices in water treatment, and well use patterns. The well design, selection of materials, or deficits in construction may cause corrosion, extra chemical oxidation or restrictions in screens, pipes, valves or channels for infiltration of undesirable microorganisms.**

**Extended periods of non-use or occasional use allow fouling growths to build up. Overuse may draw in poor quality ground water or aggravate clogging build up by encouraging sand or mineral clogging and extra oxidation.**

**3.Physical Plugging of the Formation and Screen**

**Almost all wells experience some loss in specific capacity over a period of time. This results from the slow movement of fine particles into the well area vicinity where they prevent water from flowing into the well.**
**As the pathways for normal water flow into the suction area decreases because of the accumulation of fines, the water flow velocity increases, creating turbulence in the well area. This increased turbulence heightens the movement of fines into the well suction area, increasing sand pumping, often to unacceptable levels.**
**To prevent or significantly delay any well capacity degradation caused by the movement of fines, special attention must be adhered to in order to ensure proper well development during initial well construction.**

**Suitable well development will stabilize the near well area so that subsequent pumping cycles do not trigger the movement. of sediments The thorough removal of the clay particle residues of drilling fluids used during construction will also be eliminated through proper well construction.**

**The erosion of the screen to the point where replacement or other actions need to be taken, can result from pumping in screen wells.**
**4. Corrosion**

**Corrosion leading to well performance damage may include one or more of the following forms:**

- **Failure of the well casing in the forms of holes allowing fines to enter the well resulting in sand pumping.**
- **Deposition of the products of corrosion, thereby reducing the size of the pathways of water flow to the suction area and well yield.**

- **Inflow of low quality water caused by casing corrosion (holes).**
- **Reduction in strength of the casing or well screen to the point of complete failure.**

**Some research indicates that "suction flow control devices" can be successfully used to prevent sand pumping even in some cases of casing failure. Please see "Recent Innovations…." below for a more detailed discussion of SFCD.**

**<u>Traditional Methods of Well Rehabilitation for Incrustation, biofouling, and physical plugging of the formation.</u>**

**All references checked in the preparation of this CEU note the importance of periodic water quality monitoring as the first step in successful preventive maintenance or early intervention for rehabilitation. Water quality deterioration is an early indication of the need for some type of intervention. And early intervention is far more cost effective than later intervention, when the measures taken will need to be more aggressive, more expensive, and may be less effective.**

**Periodic visual inspections and notation of water taste, odor, and turbidity can also be early warning signs of the need for intervention.**

***<u>All interventions should be designed around testing and analysis, not subjective judgment.</u>***

**It is widely accepted that "blended" or combined approaches yield better results than techniques employed alone. The combination approach works better for well development and also for well rehabilitation.**

**Well rehabilitation chemicals**

**Many of hazardous chemicals are used in well rehabilitation. They must be handled in ways that recognize the dangers involved, and used and disposed of by those understanding the proper procedures for use and disposal. Failure to do so may endanger personnel, the user of the well water, and the environment.**

**Acids have been the used for decades in the treatment of wells. Strong acids are used more frequently than any other type of chemical for well rehabilitation.**

**Hydrochloric Acid [HCL], (also referred to as muriatic acid)**

**HCL is the most effective acid for removing mineral scale but it is dangerous to handle, and gives off toxic, potentially lethal odors.**

**Hydrochloric acid is typically used with an inhibitor that minimizes the acid's corrosive effect on any metal casing, pump components and screen. It is commonly injected into the well through a tremie in a volume appropriate for the well area and surrounding formation area to be treated.**

**Surge blocks or jetting tools are used as mechanical surging to better expose the acid to the incrustation area ensuring maximum removal.**

**The contact time that the acid remains in the well water may vary from a few hours to 15 hours after the acid solution has been introduced and agitated. The well water PH is measured as an indication that the acid has reacted with the encrustation to the degree that the acidity of the solution had been lost and all possible reaction has been completed for this session. When the well PH has reached 6.5-7, the well is agitated again so the solution can be pumped to waste in an approved manner.**

**Acids may be used with benefit in both screen wells and rock wells. It is not uncommon after a successful acid treatment for the well's capacity to increase beyond its initial capacity at construction.**

**Other acid forms used are as follows:**

**Although HCL (hydrochloric or muriatic acid) has the longest history of use as a well cleaner, other acid forms are also used.**

**Sulfamic acid is not as aggressive as HCL, but since it is available as a powder, it is easier to transport and handle. In addition, it gives off less concentrated toxic fumes than HCL which also proves beneficial. Inhibiting agents, as mentioned previously, which limit the acid's attack on casing, pump and screen metallic parts are often mixed with sulfamic acid. The acid pellets can be placed directly in the well without the hazards of mixing on the surface. Sulfamic acid should not be confused with sulfuric acid, a highly aggressive acid seldom used in well rehabilitation. As with HCL, sulfamic acid is agitated to increase its contact with the encrusted area.**

**Hydroxyacetic Acid (glycolic acid)**

**Less known and less used than either HCL or sulfamic acid, hydroxyacetic acid is safer to use and has the benefit of being a bacteriacide and will directly attack and kill iron bacteria. It works the slowest of the three acids mentioned, so its contact time in the well will be the longest to achieve the desired effect. Hydroxyacetic acid is relatively non-corrosive and produces no fumes.**

**The method of application is the same as for the other two acids previously discussed.**

**Mechanical Methods to Remove Incrustants**

**A couple of effective means for removing incrustants from inside the casing and well screen are wire brushing and scraping. The loosened material can be removed by air lifting, bailing, or other means. This approach may be a good first step in rehabilitation as it may allow greater access to the formation for chemicals to be introduced later.**

**Controlled blasting is another mechanical technique for improving well yield. Controlled blasting in rehabilitation work is performed to fracture and break up large incrusted areas in the hope of allowing water to flow to the suction areas. This technique is usually performed by specialized companies.**

## Other Chemical Treatments

### Shock Chlorination

**Shock chlorination is broadly used to limit the iron bacterial growth. The shock chlorination approach is widely used in the rehabilitation of wells severely plugged by biofouling bacteria. Concentrations as high as 500-2000 ppm are used.**
**Once injected into the well, water is added to force the chlorine mixture out into the formation. Agitation is always recommended to increase surface contact between the biofouling agents and the high concentration chlorine solution.**

**Mechanical brushing, agitation, surging, jetting are all used to increase the turbulence of the chlorine solution in the well. As repeatedly stated, a multi-step or blended approach to rehabilitation, produces a superior result.**

**Shock chlorination may be used as the first step, then acidization of the well (*note- the well must be fully purged of the chlorine solution before acidization*) with agitation to improve removal of encrustants, and thirdly another shock chlorination treatment. Chlorine based approaches are more effective the longer the contact time between the chlorine solution and the biofouling agents.**

**Disposal of the waste water after both the shock chlorination and the acidization must be done with awareness of safe disposal procedures.**

### Use of Heat

**Heat can be used to increase the effectiveness of chemical treatments in well rehabilitation. Well water is withdrawn, heated and recirculated into the well to increase the action of chemical solutions. Several specialists in rehabilitation routinely employ heated chemical treatments as part a blended of a multi-step approach to well remediation. Heat alone can also be an effective biofouling removal method where chemicals cannot be used.**

**The following review of "Recent Innovations in Well Rehabilitation Methods" has been edited from material presented by Stuart A. Smith, MS, CGWP, a specialist in well rehabilitation (www.groundwatersystems.com). Mr. Smith's material was originally presented to the *15th National Congress on Water* held in Argentina in 1994 and has been updated continually.**

**We gratefully acknowledges Mr. Smith's work and his willingness to allow others to use it. Trademarked, branded, and/or patented process or products are descried below. We present this information for educational purposes only and take no position on the processes or products mentioned.**

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**Edited material follows from Mr. Stuart Smith**

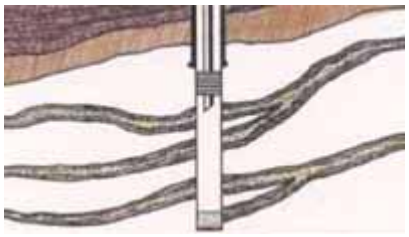
**Three representative development areas will be discussed here. All are "new" in the sense of being different than the routine, but *all are derivative and not revolutionary*. That is in itself an important fact to know: there are STILL no miracle cures. The key is to understand the strengths and weaknesses of any process and to use the best mixture in an informed manner.**

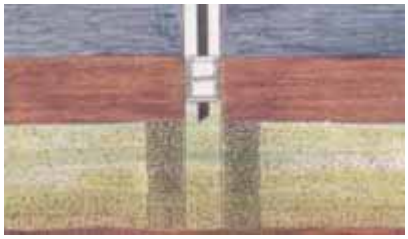
## Aqua-Freed, and other derivative concepts

***Aqua-Freed™ process: cold $CO_2$ fracture opening and encrustation removal (often called "freezing").*** **While "dry ice" (solid $CO_2$) has long been used as a well development tool in North America, control of dose and application have been a problem.**

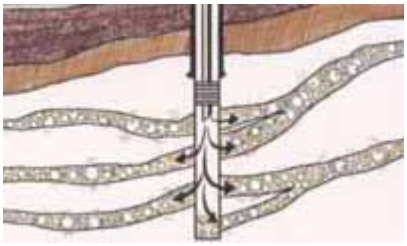
**The patented AQUA FREED process is explained below:**

**Step One:** **AQUA FREED personnel study the well data to determine the correct placement of the packer. After the pump is pulled a packer is inserted to the desired depth to confine and direct the carbon dioxide to the treatment area.**



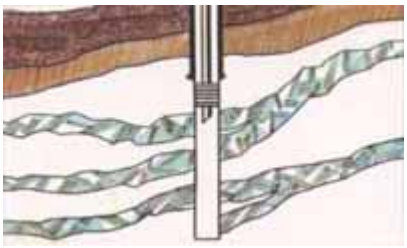


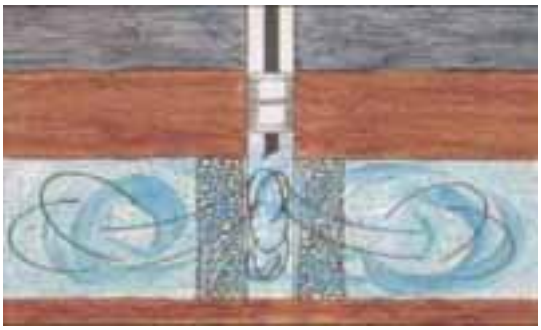
**Step Two:** **Gaseous carbon dioxide is injected through the packer into the well; producing a highly abrasive carbonic acid solution and penetrating far into the surrounding formation.**



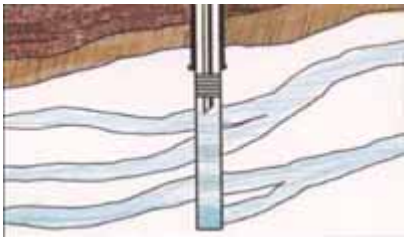
**Step Three:** **Liquefied carbon dioxide is injected at various temperatures and pressures. When the liquefied carbon dioxide comes in contact with the water, it expands rapidly, producing tremendous agitation. The continued, controlled injection, of the liquefied carbon dioxide assures the freezing of water within the formation around the well, resulting in superior disinfection and**

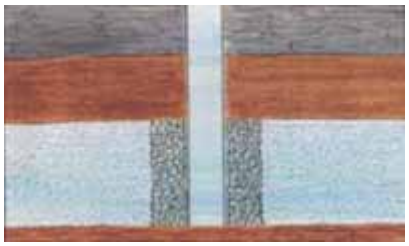
**dislodging of mineral encrustation.**





**Step Four:** **After treatment the well is mechanically developed using surge/airlift methods to remove the newly dislodged particulate matter from the well and formation. The well pump is then reinstalled and the well returned to service, providing and increased supply of water for its intended use.**





**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 $CO_2$ in a controlled manner. In its simplest form, this process has four steps as follows:**

**(1) Injection of cryogenic liquid $CO_2$,**
**(2) Allowing time for penetration into the formation and reaction,**
**(3) After application, venting and depressurization,**
**(4) Repeating as necessary.**

**A more advanced process has been developed for larger-diameter, high-volume wells, according to the company:**

**(1) Install a packer to confine a desired interval in the well. Begin injection of $CO_2$ vapor at predetermined and controlled pressures.**
**(2) Begin controlled injection of liquified $CO_2$ in pulses.**
**(3) Inject liquified $CO_2$ at temperatures and pressures that "will encourage the liquid to change to $CO_2$ 'snow'" (temp as low as -110F), freezing water in the formation around the well.**
**(4) Remove packer and thaw.**
**(5) Surge or airlift for final development. (This is crucial, as Mansuy, 1999 notes.)**
**(6) Some Aqua-Freed service providers will add a chemical rehabilitation step and additional redevelopment at this point as needed. This is highly recommended.**

**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), and no other chemicals are necessary.**

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

**(1)Commercial restriction (exclusive territories). Compare apples to apples in proposal review.**
**(2) Possible structural damage to the well- probably a declining situation as service providers gain experience.**
**(3) The cold thermal shock is admittedly not nearly as effective as can be applied by <u>heating the water</u> (see *Use of Heating above*).**

**(4) Kinetic force generated is readily dissipated in hydraulically highly conductive aquifers and is most likely confined to discrete channels.**
**(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) 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 forbidden.***

**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).**

## <u>Chlorine Alternatives for Biofouling Removal</u>

**The use of chlorination in wells is becoming more restrictive in parts of North America and Europe. Due to this and because shock chlorination is seldom the most effective treatment, several other treatments are being used for biofouling control.**

***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 H2S 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...**

***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 preventive maintenance treatments.**

**The biofouling bacteria often 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 organic compounds (those famous disinfection byproducts DBPs).**

**Chelating organic acids such as acetic or glycolic acid have both antibacterial effects 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.**

***Use of heat:* 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. Alford and Cullimore (1999) provide a useful experience history. It 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.**

**Often the best approach to using heat is as a part of the blended chemical heat treatment method described in the <u>following</u>.**

***New chemical products:* Are they Effective and safe? Proof that well rehabilitation has become a notable market factor in North America has been the new 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 sulfamic, acetic, and citric acid, or caustic soda, often with 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.**

**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.**

**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 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 alwways a bad thing 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 glycolic acid, with its own high pK and NSF certification, is a safer, more versatile alternative.**

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**Blended Method Treatments**

**<u>One trouble in considering chemical treatment types individually is that they seldom work to best advantage alone.</u> 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 maximum effect. Chemical activities can be otherwise augmented by mixtures and temperature increase.**

**(2) 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.**

**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 who wash dishes know that cleaning is most effective with detergent, hot water, and agitation and scrubbing.**

**The patented BCHT process (developed by ARCC Inc., Daytona Beach, 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 (Leach et al. 1991; Kissane and Leach, 1993; Alford and Cullimore, 1999).**

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

Biomass Recovery after BCHT

Biomass Recovery after BCHT

**(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 (Alford and Cullimore, 1999).**

**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 acetic or glycolic acid) amended with nonphosphate (polyelectrolyte) surfactant into the production zone (phosphates may remain to cause growth). 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 and 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 (e.g., Borch et al. 1993; Smith, 1995).**

**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.**

**The Ultra Acid-Base process or UAB™ is a less technically intensive variation on BCHT (developed by the Prairie Farm Rehabilitation Initiative in cooperation with ARCC Inc. associates Droycon Bioconcepts in Canada) that inflicts contrasting extremely acidic and caustic environments on the biofouling in a system.**

**The treatment process involves three phases of chemical application to remove the clogging biofilms. As with BCHT, the first phase is intended to shock the bacterial cells and biofilms, the second to disrupt (break up) the biofilms, and the third to disperse the biofilms and other clogging material.**

**The shock phase of the UAB treatment process begins after pre-heating the well intake area with hot water to increase the down hole temperature to about 65 C. The shock phase itself involves application of a hot water solution, disinfectant or detergent acid such as acetic, and nonphosphate wetting agent surfactant). The water in the well and surrounding aquifer is maintained at a temperature of at least 65 C, to enhance the chemical effect. High temperatures increase the rate at which chemicals react and reduce the amount of chemical needed for cleaning. The wetting agent helps the hot water and chemicals to penetrate the biofilms.**

**The disrupt phase works to kill bacteria by causing a shift from a strongly acidic to a strongly alkaline solution. Although some bacteria thrive in acid conditions and some in caustic environments, none (including those adapted for circum-neutral pH environments) do well when rapidly shifted to another environment. This process has been highly effective in applications in the U.S. and Canada.**

**The developers of both processes have been able to fully train several crews to date, and general application may require an unprecedented training effort. This need for training has restricted somewhat the application of BCHT. It is (in the author's opinion) worthwhile to obtain the training to employ these very effective approaches. The payoff is in being able to supply a very effective treatment using locally available resources and equipment, with little or no chemical disposal after treatment.**

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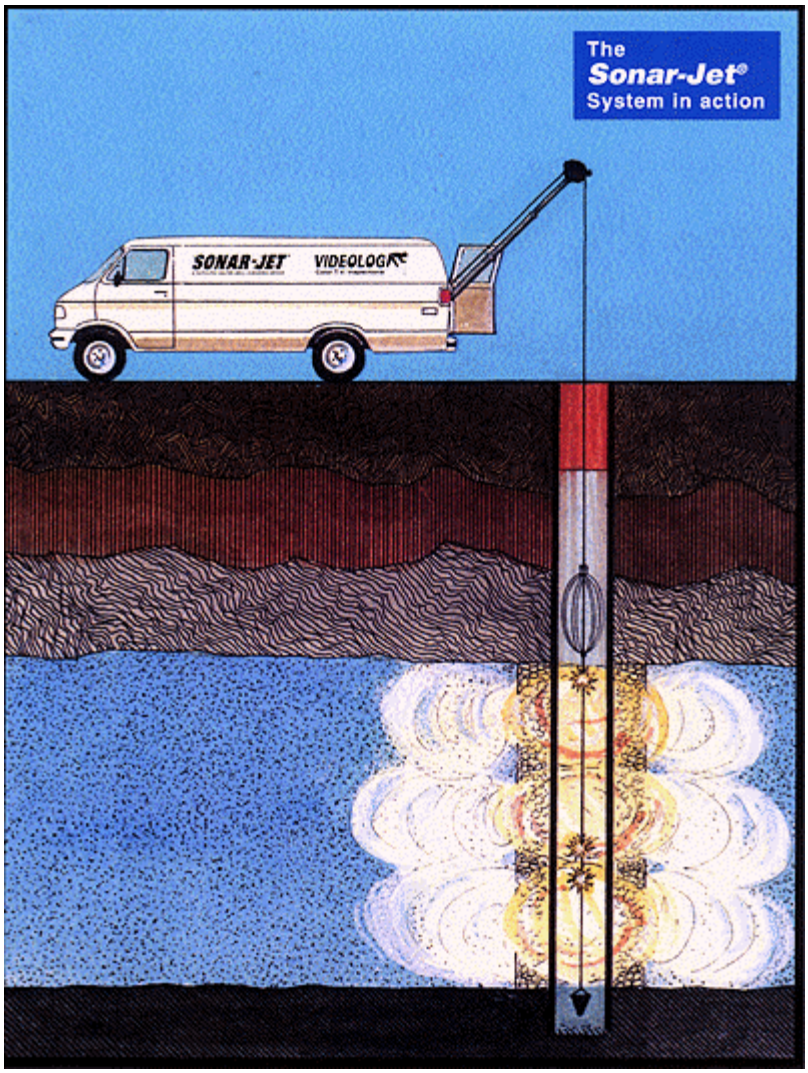
**Improving the application of force in redevelopment is a crucial area of improvement. Among these are treatments based around detonating a shaped or charged wire, cord or device in wells. This cleaning approach has been in common use in the water and oil industry for several decades.**

**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 pacl surfaces. 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 45 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.**

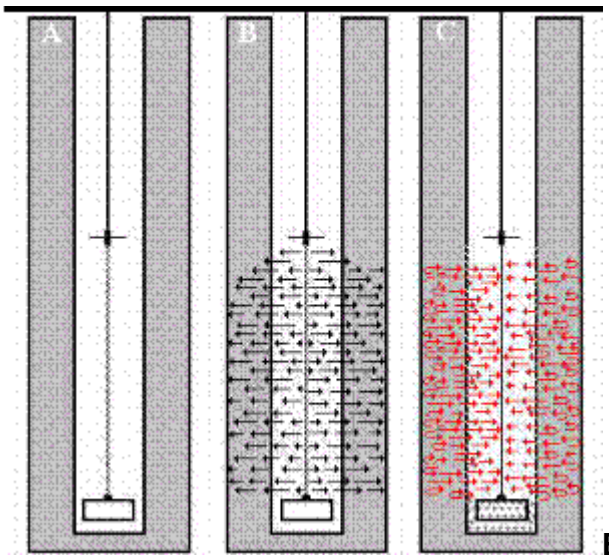
**2. Pulsating, horizontally directed, gas pressure jets fluid at high velocity back and forth through the perforations to deep clean the productive aquifers.**

**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.**

**Beginning April 1, 1997, all Sonar-Jet® devices manufactured were of a new and improved version:**

**(1)Force capacity was doubled, "while still considered safe."**
**(2) A wider range of in-well devices for vaious applications, including PVC casing.**
**(3) Better cleanup of Sonar-Jet debris to eliminate pump clogging.**

**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.**



**EnerJet Detonating**

**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."**

**Sonar-Jet or Ener-Jet type cleaning has typically been considered optimal for near-well, hardened deposits, and has been not so effective on soft, biofouling plugs, which can be forced outward into the formation by the harmonic step.**

**However, 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 Sonar-Jet treatment**
**(4) Follow immediately with a chemical and redevelopment step**
**(5) TV, pump test and review**

**The Shockblasting Method:**

**The Shockblasting® method (Berliner Wasserbetriebe, BWB), is described to illustrate how these methods arise independently around the world. This system also works with small amounts of explosives along a cord, utilizes the elastic impulses and the pressure of the gas fumes which arise along the whole length of the filter. Modern explosive cords, which are available**

**in different charge quantities, are used to produce the detonation. The charge quantity which is necessary for the optimal outcome of the regeneration of the well depends on:**

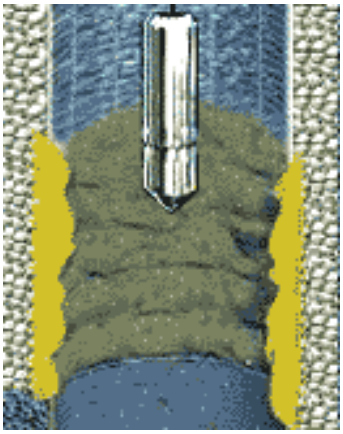
**(1) The nominal width of the filter pipe**
**(2) Type and quality of reinforcement materials**
**(3) Type, age and intensity of the sedimentation.**

**As with Sonar-Jet and Ener-Jet, the well is initially brushed and pumped out, TV surveyed, loaded with the device, "shot" then the deposits are removed conventionally by pumping out the debris. "Afterwards, an intensive de-silting of the filter is carried out meter for meter." BWB says "Findings gained from experience for the effectiveness and usability of Shockblasting® in wells made of different materials and from compregnated laminated wood are available."**

***Andreas Wicklein of BWB further 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."***

**The ProWell device:**

**This device, developed in Israel by ProWell Technologies, Inc. develops based on high-pressure gas pulses which are generated by a special apparatus. Advantages:**



**(1) Highly efficient action of shock wave and strong surging without utilizing explosives.**
**(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 R&M technique.**

**"When used in conjunction with chemicals, the ProWell method enhances the treatment efficiency and decreases the amount of chemicals applied and the treatment." We ourselves have no experience with this process.**

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**Suction Flow Control**

**In any well, the pump represents the lowest pressure point in the aquifer volume affected by the well.**

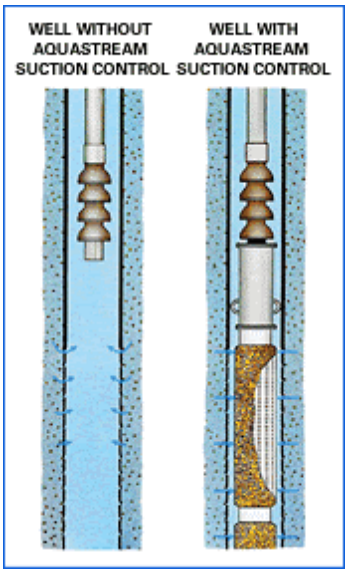
**Where the pump is situated in the casing above the screen, almost all flow enters through the top 10 to 15 % of the screen (Nuzman, 1989; Pelzer and Smith, 1990; Ehrhardt and Pelzer, 1992). If the pump is situated in the screen, flow through the screen occurs predominantly near the pump.**

**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). 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.**

**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 similar process was developed by Rudolph Pelzer of Herzogenrath, Germany. This design has been marketed under the Eucastream mark by Kabelwerk Eupen, Eupen, Belgium, and EUFOR S.A. (Liége, 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.**

**New Devices and Materials**

**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 (Certa-Lok™), and flexible Wellmaster™ (Kidde Fire Fighting, Angus Fire, North America, Angier, NC) discharge hose that permits easy pump service while providing reliable, high-strength, corrosion-resistant material.**

**Computers and controllers: SCADA systems originally developed for process treatment can be adapted for wellfields, permitting rapid, easy, and continuous monitoring of well and pump hydraulic performance, and even physical-chemical changes. 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 <u>systematic preventive maintenance</u> 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.**

**It is strongly recommend that competent, experienced professionals are retained to troubleshoot issues with wells and carry out remediation solutions. It is always prudent to get a second opinion from well-respected professionals who have expertise in well construction and restoration.**

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