Water Well Performance Solutions

Better Wells with Chemicals

COTEY CHEMICAL CORPORATION®

Introduction

- Kevin McGinnis, President of Cotey Chemical Corporation
- Providing water well maintenance, rehabilitation & development products and services to the industry since 1949

Better Wells with Chemicals

Topics of Discussion

- Chlorine use and misuse in water wells
- Well rehabilitation
- Well maintenance

Better Wells with Chemicals

Sterilizing Chemicals

- Calcium Hypochlorite - granular 65-70% chlorine
- Sodium Hypochlorite - liquid, 5-10% chlorine
- Hydrogen Peroxide
- New chemistry

Better Wells with Chemicals

Calcium hypochlorite

Dry granular/powder 65-70% available chlorine aka HTH

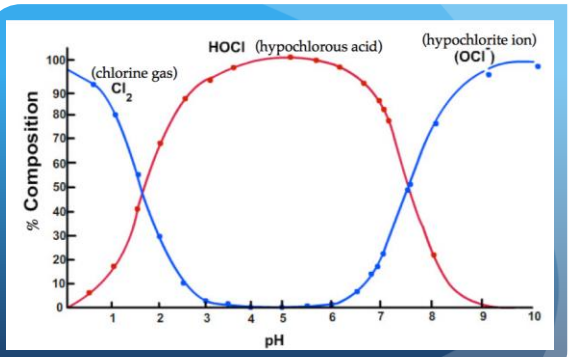
- Advantages
  - Inexpensive
  - Easy to find
  - Easy to handle
  - Relatively good “shelf-life”

Better Wells with Chemicals

Calcium hypochlorite

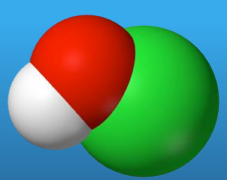
- Disadvantages
  - Reacts with other chemicals, use caution when storing, could cause fire
  - Not very effective at penetrating bio-films
  - Calcium combines with the bicarbonate in the water to form calcium carbonate. Thus, premix and filter the solids before introducing into the well.
  - Generates heat when added to water so always premix in a sufficient volume of water
  - Raises the pH of the water which could reduce the production of hypochlorous acid (HOCl). HOCl is the most efficient disinfecting part of the reaction. For best results use with a pH adjuster.

Better Wells with Chemicals



Free Swimming Bacteria

Slime Biofilm



HOCl (hypochlorous acid)

H_2O (water)

Sodium hypochlorite

Clear to yellow liquid, commonly called bleach, with 5-12% available chlorine.

- Advantages
  - Inexpensive
  - Easy to find
  - Easy to handle
- Disadvantages
  - Not very stable - thus has low "shelf-life"
  - Not very effective at penetrating bio-films
  - Raises the pH of the water which could reduce the production of hypochlorous acid (HOCl). HOCl is the most efficient disinfecting part of the reaction. For best results use with a pH adjuster.

Hydrogen peroxide

Liquid, available in 8-90% concentration with 30% being the most common

- Advantages
  - Very effective at breaking down biofilms and killing bacteria
- Disadvantages
  - Corrosive to skin and lungs - use caution when handling
  - Could stimulate aerobic bacterial growth because it breaks down into oxygen and water

Wel-Chlor *Plus*

The *New* Chlorine - white solid, 56% available chlorine

- Superior performance - mixes pH neutral so pH adjustment is not required
- Safer - less fuming than other chlorine products
- Longer "shelf life" - the molecule is more stable
- Dissolves 5x faster than calcium hypochlorite and without calcium scaling
- Easier to handle and ship - Not considered hazardous by DOT
- NSF Standard 60 approved for use in all types of water wells

Limitations of chlorine products

- Chlorine does not dissolve the hard mineral deposit which is the primary plugging problem in water wells.
- Chlorine is limited in its ability to penetrate slime (biofilm) in a water well.
- Chlorinating a water well is simply a “snap-shot” of disinfection. Once the pump is turned on the chlorine is evacuated and the bacteria begin to re-colonize the well.

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Chlorine enhancers

- Blend of buffered acids, surfactants and polymers.
- Used to improve the effectiveness of sodium and calcium hypochlorite by 100x.
- Proprietary blends
  - Cotey Chemical Corp. - Chlorine Enhancer
  - Jet Lube (formerly Design Water Technologies) - Chloropal
  - Johnson - NW 220
  - Layne - Oxymate

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Approximate quantities of chlorine compound required to produce a chlorine concentration of 100 parts per million.

Gallons of Water in Well	Liquid Bleach (5 percent)	Calcium Hypochlorite (65 percent)
250	½ gallon	0.32 pound
500	1 gallon	0.65 pound
750	1½ gallons	0.97 pound
1000	2 gallons	1.30 pounds
1500	3 gallons	1.95 pounds
2000	4 gallons	2.60 pounds
2500	5 gallons	3.35 pounds
3000	6 gallons	3.90 pounds
3500	7 gallons	4.55 pounds
4000	8 gallons	5.20 pounds
45000	9 gallons	5.85 pounds
5000	10 gallons	6.50 pounds
7500	15 gallons	9.75 pounds
10000	20 gallons	13.00 pounds

ith Chemicals

Topics of Discussion

- Benefits of well rehabilitation
- Causes of well yield decline
- Diagnosing the problem
- Mechanical methods
- Mineral & organic acids
- Rehabilitation procedure

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Benefits of well rehabilitation

- Savings in energy costs
- Increasing the life of the pump
- Extending the life of the well
- Restoring lost capacity
- Improving water quality (i.e. turbidity, color, taste, safe bacti samples, etc.)

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Cause of Well Output Reduction

- Lowered water table by depletion of the aquifer
- Reduced pump efficiency due to worn, corroded or plugged pump parts
- Mineral precipitation such as iron, calcium carbonate and/ or magnesium carbonate
- Slime formation (bio-fouling) caused by iron bacteria
- Microbial corrosion caused by sulfate-reducing bacteria
- Mud, sand and silt fouling from sagging strata or gradual buildup around the screen and gravel pack

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Three general categories of bacteria: slime forming, iron related, and sulfate reducing bacteria.

- Bacteria are naturally-occurring, and ubiquitous
- We find bacteria in interrelated colonies, rather than independent groups
- Iron related and slime forming bacteria commonly grow in aerobic conditions
- Sulfate reducing bacteria commonly grow in anaerobic areas such as beneath scale nodules or in deep well environments

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Biofilm in a water well

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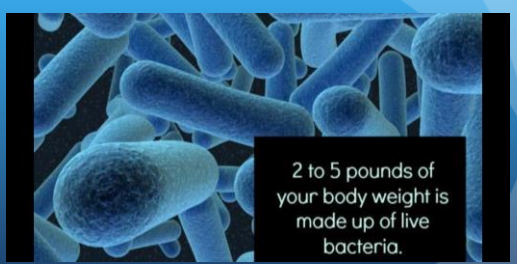
Not all bacteria is bad



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What encourages bacterial growth?

- Available nutrients in the water such as
  - organic load in the ground water
  - oil from oil-lubricated turbine pumps
  - ground water contaminants such as hydrocarbons
- Available oxygen
  - exposing screens while pumping
  - pump cycling
  - cascading water into the well

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Iron encrustation of drop pipe Biological & Chemical reaction to steel

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Diagnosing the Problem

- History of the well (including SC history)
- Review of the well log (geological formation)
- Down-hole video inspection
- Materials of construction & well design
- Scale analysis
- Water analysis
  - chemical
  - biological (generally not a very accurate measure)

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Select rehabilitation method

- Over-pumping or rawhiding
- Mechanical surging – single or double disk surge block
- Brushing
- High velocity air/water jetting
- Percussion

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Select rehabilitation method

- Airburst® by Bolt Technologies
- Airshock by ProWell Technologies
- Ener Jet by Welenco
- Shockblasting® by Berliner Wasserbetriebe
- Sonar-Jet® by Water Well Redevelopers
- Aqua-Freed™ by Subsurface Technologies
- Blended chemical solutions

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Mechanical rehabilitation methods

- Advantages
  - Removes interior screen deposits
  - Environmentally "friendly" - No chemical disposal
- Disadvantages
  - Difficulty in getting energy to penetrate through the screen
  - Difficulty in breaking down the hard cement-type deposits with percussion alone

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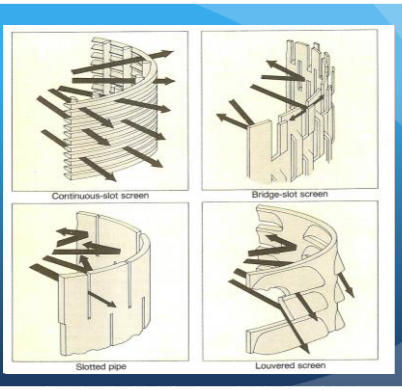

Bacterial growth

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Hard mineral scale buildup

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Severe buildup of iron & manganese

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Combining chemical and mechanical rehabilitation methods

- Mechanical cleaning prior to injecting chemicals removes interior screen deposits. This ensures more uniform chemical access outside the screen and into the formation
- Takes a lot of energy to remove all of the cemented deposits in a water well – both mechanical and chemical energy are needed

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Mechanical Pre-cleaning – brushing

- Removes interior screen deposits which ensures more uniform access of the chemical or mechanical energy into the formation.
- Potentially reduces the amount of chemical needed to rehabilitate well.

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Better Living Through Chemistry

It's not just chlorine and acid anymore…

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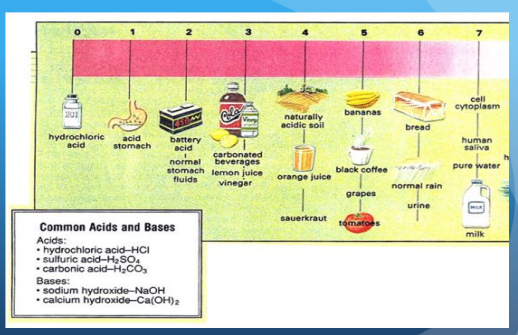
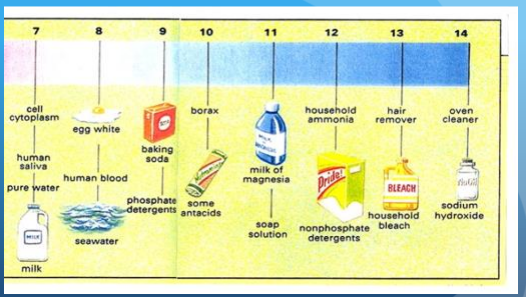


Better Wells with Chemicals



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Mineral Acids

generally used to dissolve hard mineral encrustation

- Hydrochloric (HCl)
- Phosphoric
- Sulfamic

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Hydrochloric acid

aka muriatic acid, liquid acid usually 31-35% acid concentrations. Recommend using 5-10% concentration in well volume.

- Advantages
  - Inexpensive
  - Easy to find
  - Effective against: calcium carbonate, iron, manganese and to a lesser extent calcium sulfate
  - Fast reacting

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Hydrochloric acid

- Disadvantages
  - Not very effective against bio-films
  - Dangerous to handle and transport
  - Evolves dangerous gases
  - Not recommended on galvanized applications
  - Causes stress cracking on stainless steel if inhibitor is not used
  - Technical grades can contain heavy metals, arsenic, etc. Try to find food grade or NSF approved product.
  - Rapidly evolves carbon dioxide when used in limestone formations, which can cause a blow out of the chemistry

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Phosphoric acid

Liquid – usually available in 75% & 85% acid concentrations

- Advantages
  - Readily available in both food grade and NSF-certified quality
  - Does not give off harmful vapors
  - Very effective against iron & manganese because of its sequestering ability

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Phosphoric acid

- Disadvantages
  - Slower reacting than hydrochloric acid
  - Not very effective against phosphate because of similar ion concentration
  - Not very effective against biofilms
  - Contains phosphorous which can be a nutrient boost for bacterial when oxidized with chlorine.
  - Will cause environmental concerns if discharged to a storm sewer – promotes algae and cyanobacterial growth in surface waters.

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Sulfamic acid

Granular – 98-99% acid concentration

- Advantages
  - Safer to transport & handle than liquid acids
  - Dry form does not give off dangerous fumes
  - Spills are easily cleaned up
  - Strong acid when mixed with water
  - Effective against calcium carbonate

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Sulfamic acid

- Disadvantages
  - Not quickly dissolved in water; recommend premixing before introducing down the well
  - Not very effective against sulfate deposits such as calcium sulfate (gypsum) because of similar ion
  - Very slow at dissolving iron & manganese

Better Wells with Chemicals

Proprietary blends

- Baroid – AquaClear MGA
- CETCO – DPA
- Cotey Chemical Corp. –

  Dry Acid Special, Liquid Descaler
- Jet Lube (formerly Design Water Technologies) – Unicid Granular
- Johnson – NW 100/110/120
- Laval – Boresaver IKL

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Organic Acids

generally used to penetrate and disperse biofilms

- Glycolic Acid
- Glacial Acetic Acid – Vinegar
- Citric Acid
- Oxalic Acid

Better Wells with Chemicals

Glycolic acid

aka hydroxyacetic acid, liquid acid most commonly used in 70% acid concentration. Recommend using 3-5% concentration in well volume. Manufactured by DuPont.

- Advantages
  - Penetrates bio-films & kills bacteria
  - Chelates (ties up) metal ions
  - Produces few toxic fumes
  - Relatively non corrosive to most metals
  - Good acid to use as a pH adjuster prior to chlorination
- Disadvantages
  - Generally considered weak against mineral scales, thus recommend using with strong mineral acid

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Acetic acid

Liquid acid usually supplied as glacial acetic acid. Also known as vinegar in its weaker form. Recommend using 3-5% concentration.

- Advantages
  - Effective at removing sulfates
  - Removes organics
- Disadvantages
  - Very corrosive to skin
  - Vapors corrosive to lungs
  - Dangerous to handle and transport

Better Wells with Chemicals

Proprietary blends

- Baroid – AquaClear AE
- CETCO – LBA
- Cotey Chemical Corp. –

  Dry Acid Special, Liquid Descaler
- Jet Lube (formerly Design Water Technologies) – Unicid Catalyst
- Johnson – NW 310
- Laval – Boresaver BLS Liquid Enhancer

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Rehabilitation Procedure

- Video the well
- Pre-clean the well with a brush, percussion tool or other tool to allow better penetration of chemical or mechanical energy.
- Remove the loosened material from the bottom of the well using a bailer, air-lift device or suction device.
- Pour chemical into the top of the well or premix and inject into the screen area.
- Agitate aggressively every few hours with a brush, surge block or other tool to force the chemical into the gravel pack and formation.
- When using acid – check the pH of the water often, if the pH is above 3.0 then add more chemical. pH should remain at or below 3.0 for the 24-48 hour treatment period.
- Remove the chemical from the well.
- Develop the well. Spend extra time and energy to remove the sand, silt and partially dissolved material trapped in the gravel pack and formation.
- Video the well

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Case study - Lajitas, TX

New public supply water well:

1,120' deep	Pump set to 400'
Static water level 162'	Produced 135 gpm
Drawdown 228'	Specific capacity 0.59

Formation - fractured limestone

Treated with Dry Acid Special and surge block.

Static water level 162'	Produced 285 gpm
Drawdown 10'	Specific capacity 28.5

48x improvement in specific capacity

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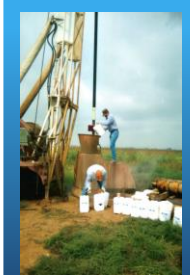
Better Wells with Chemicals



Clovis, New Mexico

Rehabilitating an old ag irrigation well to convert it to a public supply well:

380' deep	Pump set to 350'
Static water level 284'	Produced 125 gpm
Drawdown 66' breaking suction	Specific capacity 1.89

Formation - sand and gravel

Treated with Liquid Acid Descaler & Cotey Well Cleaning Brush

Static water level 284'	Produced 235 gpm
Drawdown 42'	Specific capacity 5.60

196% improvement in specific capacity

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Well for Coca Cola Bottling Company in Mexico.

This well recovered 3.51 m static level after rehabilitation

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Case study - Hermosillo, Sonora, MX

Four year old agricultural irrigation water well:

Drilled 550' deep	Pump set to 520'
Static water level 275'	Produced 600 gpm
Drawdown 245'	Specific capacity 2.45

Problem: Loosing production as a result of severe biofouling, with heavy iron bacteria and oxide deposits.

Treated with Liquid Descaler and scrub brush.

Static water level 275'	Produced 1,600 gpm
Drawdown 100'	Specific capacity 16.0

553% improvement in specific capacity

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Rehabilitation treatments can involve many different strategies, however, they must:

- Achieve effective deposits removal
- Be custom tailored, based upon cause of the problem, well construction and type of formation
- Have penetration into the surrounding formation
- Have good agitation

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Topics of Discussion

- Longevity of success factors
- Preventive maintenance
- Limitations of specific capacity
- Cost to replace a well
- Graph – typical life of a water well

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Longevity of Successful Factors:

- Rehabilitation often does not remove 100% of the deposited mass.
- After treatment bacteria can re-grow very quickly on organic material left behind.
- Key to increasing time between treatments is effective deposit removal.
- Consider preventive maintenance.

Better Wells with Chemicals

Why wait until it gets this bad? *Preventive maintenance makes cent$*

Better Wells with Chemicals

Preventive maintenance makes cent$; the *Proactive* approach

- Schedule maintenance during slow times.
- Don't have to pull the pump.
- Less down time compared to full rehab.
- Less chemical needed since buildup is thin and relatively soft.

Better Wells with Chemicals

Preventive maintenance makes cent$; the *Reactive* approach

- High expense to pull the pump and perform full rehabilitation.
- Longer down time to perform full rehabilitation.
- Pump/well fails at the most inopportune times, usually during the most critical water need. This forces you to expedite services and supplies in crisis.
- The greater the buildup (down hole) the greater the possibility of not restoring the lost capacity and the greater the risk of losing the well altogether.

Better Wells with Chemicals

Why wait until it gets this bad?
Preventive maintenance makes cent$

Better Wells with Chemicals

Corroded well casing

Better Wells with Chemicals

Why wait until it gets this bad?
Preventive maintenance makes cent$

Better Wells with Chemicals

Preventive maintenance makes cent$

- The goal of rehabilitation is to remove 100% of the plugging material. However, most rehab projects fall short of the goal because:
  - Time limits – many projects require procedures to be repeated until all of the plugging material is removed, yet shutting down a well for more than a few days is simply not feasible.
  - Money limits – restoring a well to its original specific capacity can be labor and material intensive, thus, we settle for "good enough".
  - Lack of understanding of well hydraulics – we assume that if we bring the well back to the original specific capacity then all of the plugging material should be removed, right?

Better Wells with Chemicals

Preventive maintenance makes cent$

- Specific capacity (gpm/foot of dd) is **NOT** a very good measurement of well efficiency nor is it a very accurate measurement of severity of well plugging.
- Why? Because most wells have excess production capacity - as a producing zone begins to plug other zones are able to compensate.
- For example, with a 25% loss in SC we assume the well is 25% plugged. However, after video inspection we realize the well could be 40, 50 or even 60% plugged.
- This lends credibility to performing regular well maintenance rather than irregular well rehabilitation.

Better Wells with Chemicals

Typical costs of replacing a well

- Abandon the old well system: **$20,000 to $40,000**
- Site selection/exploration (geologic recon., test drilling, sample analysis, test well design & installation, testing and analysis): **$5,000 to $200,000**
- Design, permitting, plans & specs, bidding (10% to 15% of total): **$20,000 to $60,000**
- Soils & Materials testing (geotechnical), surveying, legal and admin: **$10,000 to $40,000**
- Property Purchase/loss of existing property: **0 to $20,000 (??)**
- Installation and start-up of well, pump, pump house: **$250,000 to $1,000,000**
- Engineering oversight, performance testing, manuals and reports: **$20,000 to $60,000**
- Installation of water main at $80 to $120 per foot: **$20,000 to $200,000**
- Electrical power drop: **$5,000 to $80,000**

Typical cost range: $350,000 to $1,700,000

Intangibles: Risk (contamination, unanticipated treatment, performance problems, etc.)

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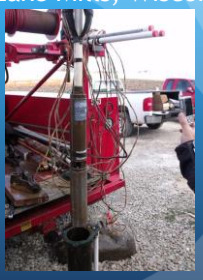
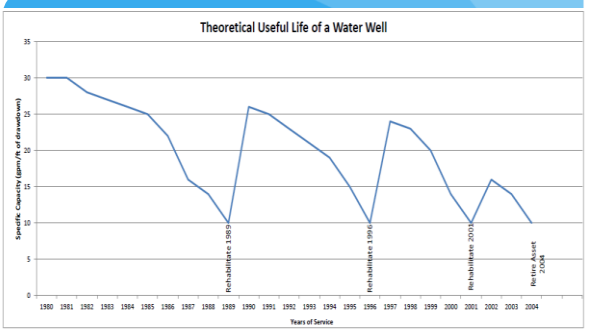
Maintenance treatment on a well for *Natural Links Farms* in Lake Mills, Wisconsin



Better Wells with Chemicals



Better Wells with Chemicals

Questions?

Resources

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- Miller, William D., PhD, *"Chemicals of Water Well & Systems: Use & Misuse"*, a Short Course. Washington, D.C. 1968
- Driscoll, Fletcher G., *"Groundwater and Wells" Second Edition*, Johnson Screens, St. Paul, MN. 55112
- Schnieders, J.H. *"Chemical Cleaning, Disinfection & Decontamination of Water Wells"*. Johnson Screens Inc., St. Paul, MN. 2003
- Smith & Comeskey, *"Sustainable Wells-Maintenance, Problem Prevention and Rehabilitation"*. CRC Press, Boca Raton, FL. 2010
- Web sites: www.ngwa.org

Better Wells with Chemicals

Bass Lake well rehab project North Judson, IN

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Before rehabilitation the well pumped 950gpm and was breaking suction

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Pull the pump

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Video inspect the well

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Brush and bail the well

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Introduce the chemical

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Brush and surge the well

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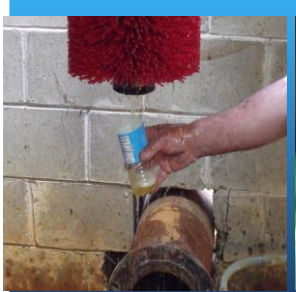
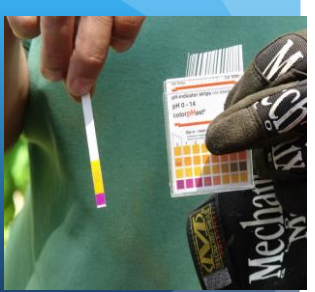
Monitor the pH and keep it below 3.0





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After purging the chemical from the well spend extra time to develop the well

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Happy customer - producing 1350 gpm

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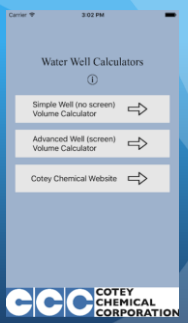
Check out the Water Well Calculator App for iPhone and Android.



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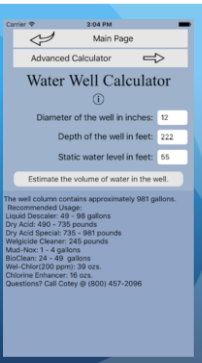
Calculates the volume of water in a well and the recommended usage of solutions for well rehabilitation or disinfection.



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