GlobalEx Water and Air Technology

GLOBALEX CHLORINE DIOXIDE (ClO^{2})

IN THE OIL AND GAS INDUSTRY

Oil & Gas Well Treatment - Downhole Chlorine Dioxide

Chlorine dioxide has demonstrated unique properties during Downhole treatments. As a true gas, even in the liquid phase, it can permeate areas of the formation and well bore that other chemicals and biocides fail to do, with or without the presence of near wellbore plugging. Chlorine dioxide is highly soluble in oil which gives it the unique ability to actually affect the wettability/surface tension of the oil promoting increased movement and flow without leaving any harmful residual. This combined with the chlorine dioxide's anti-plugging agent effect often yields increases in performance and production that are unobtainable by other methods.

Increase Well Performance

ClO2 has proven highly effective at removing plugging agents from the well bore and near-well bore formation. Our solution improves the performance of wells by addressing the following three common subsurface oil and gas field problems:

Eliminates Iron Sulfide

ClO2 has proven highly effective at removing plugging agents, such as bacteria, iron sulfide and polymer damage, from the well bore and near-well bore formation. Chlorine dioxide use history with Injection, Disposal and Producer well treatments yields immediate and sustained positive results including higher than predicted production.

Iron sulfide plugging in the near-wellbore area is a widely recognized cause of decreased well productivity. Unlike conventional acidulation, which only temporarily solubilizes iron sulfide deposits through the introduction of low pH hydrochloric acid, ClO2 solution completely dissolves iron sulfide and converts it to water-soluble iron sulfate.

Inactivates Biological Contamination

Iron sulfide deposits that cause plugging in the near-wellbore area are formed through the metabolic activity of Sulfate Reducing Bacteria (SRB) that are introduced into the well as biological contaminants during work-over, hydraulic fracturing and maintenance operations.

Environmental conditions deep within the well are typically warm and anaerobic (i.e. no "free" oxygen present). SRBs thrive under such conditions, utilizing ubiquitous sulfate as a "combined" source of oxygen to complete their metabolic cycle, leading to the formation of iron sulfide deposits and hydrogen sulfide (H2S) gas as undesirable byproducts. Chlorine dioxide is a potent biocide that inactivates all forms of microbial life with which it comes in contact, including SRBs. ClO2 solution inactivates SRBs present in the near-wellbore area, thereby preventing the formation of iron sulfide deposits that impede well performance.

Removes Polymer Damage

Well plugging by polymer products used during well drilling, hydraulic fracturing and stimulation operations is another well-recognized cause of decreased well performance. Although critical to carrying out these procedures, residual polymer material can impede well performance if it remains in the near wellbore area following completion. ClO2 Down-hole solution has been shown capable of removing such residual polymer damage. Upon contact, chlorine dioxide solution breaks apart most commonly used polymers through destructive chemical oxidation, thereby facilitating their release from the near wellbore area.

Protect Your Investment

In addition to increasing performance of oil and gas field wells, chlorine dioxide treatment process also:

- Enhances worksite safety by oxidizing any potentially dangerous H2S gas present in the near-wellbore area that might otherwise escape to the atmosphere.
- Reduces equipment damage by creating conditions within the well that are conducive to smooth operation.
- Provides a chemical tool that can be used to "unstick" process equipment such as submersible and rod pumps, thereby reducing dependence on workover rigs to maintain operations.

Frac & Produced Water Treatment and Reuse

Globalex solution is a chlorine dioxide (ClO2) treatment for surface wastewater installations in the oil and gas field environment. The solution has proven highly effective at improving water quality in tanks, reserve pits, impoundments and ponds so that the wastewater can be reused in ongoing site downhole operations such as drilling and hydraulic fracturing, or disposed of more efficiently through solar evaporation.

Globalex’s chlorine dioxide treatment process greatly improves water quality by addressing common problems that develop when wastewater produced in the oil and gas field environment is stored in surface containment basins.

Chlorine Dioxide Breaks Emulsions and Destroys Sludges

Surface storage of wastewater produced in oil and gas field operations, particularly in warm weather, creates environmental conditions which are conducive to the formation of emulsions and sulfidic sludges that prevent effective separation of the water from entrained hydrocarbons, production chemicals and particulate matter. Once emulsions and sludges have formed within a wastewater containment basin, creating a condition known as "blackwater", this mixture of water, hydrocarbons, chemicals and solids becomes completely unsuitable for reuse in site operations due to its undesirable chemical and physical properties.

Globalex's chlorine dioxide treatment reverses the reaction that natural environmental conditions caused within the wastewater that led to formation of emulsions and sulfidic sludges. Chlorine dioxide quickly breaks apart complex emulsions and destroys sulfidic sludges through chemical oxidation, allowing the water to separate from residual hydrocarbons, treatment chemicals and particulate matter present within the wastewater containment basin. Once the water has been effectively separated from other constituents by chlorine dioxide, it is typically of such high quality that it may be reused in other site operations, or be disposed of more readily through solar evaporation.

Chlorine Dioxide Inactivates Biological Contamination

The emulsions and sludges that often render wastewater at oil and gas production facilities unsuitable for reuse in site downhole operations are normally formed through the metabolic activity of ubiquitous Sulfate Reducing Bacteria (SRBs). When conditions within a wastewater containment basin become anaerobic (i.e. no "free" oxygen), which they often do because of a heavy Biological Oxygen Demand loading placed on the system by the presence of hydrocarbons and treatment chemicals, SRBs utilize sulfate as a "combined" source of oxygen to complete their metabolic cycle, resulting in the formation of emulsions and sulfide sludge's as undesirable byproducts.

Globalex's chlorine dioxide is a potent biocide that inactivates all forms of microbial life with which it comes in contact, including SRBs. When treated with chlorine dioxide, wastewater being stored within a surface containment basin is temporarily sterilized, allowing it to be promptly reused in site downhole operations without fear that the subsurface formation might become contaminated with SRBs or other potentially harmful micro-organisms present in the wastewater.

Additional Treatment Benefits

In addition to improving water quality, chlorine dioxide treatment enhances worksite safety by oxidizing Hydrogen Sulfide (H2S) gas, reduces conditions that lead to equipment damage, eliminates offensive odors by oxidizing sulfides and other reduced sulfur compounds, and reduces environmental threats to wildlife.

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DOWNHOLE

Case Studies

Oil Field Case Study: Eliminating Iron Sulfide in Oil Wells

Treating Production Well

Oil Fields

The Issue: Iron Sulfide Plugging in Wellbore

The Solution: Treatment using chlorine dioxide (ClO2) stimulation process

Background

A Texas-based oil company operates a producing field in west Texas. With a history of iron sulfide related problems, one of their wells experienced excessive workover costs and downtime.

Chlorine Dioxide Application Considerations

It wasn't unusual for the well's electric submersible pump (ESP) to plug as many as four times in a two-week period. During each two-week period, two acid jobs were completed in an attempt to correct the problem. Both stimulations proved unsuccessful and the ESP had to be replaced, costing over $21,000 plus lost production revenue.

Samples were taken from the ESP, confirming that the plugging material consisted mainly of iron sulfide and calcium carbonate.

Chlorine Dioxide Treatment Approach

A complete study resulted in the recommended use of chlorine dioxide stimulation process, to remove the iron sulfide by oxidation to a soluble form.

250 bbls of ClO2 staged with an acid containing micellar solvent, corrosion inhibitor and iron Chelan was pumped into the wellbore to remove the plugging material.

Conventional acid stimulation will solubilize carbonate and iron sulfide which remains in solution as long as the pH remains below 2. Once the acid is spent and the formation fluid pH rises above 2, the iron sulfide re-precipitates, plugging the pore spaces and the pump intake.

The ClO2 treatment enhances conventional acid stimulation by oxidizing the preferentially oil-wet hydrous ferric oxide, which is chelated, while the insoluble sulfide is oxidized to water-soluble sulfate.

Results

Iron sulfide plugged within the ESP, which cost the operator as much as $38,000 every two weeks. As a result of using the ClO2, there were no iron sulfide related pump failures in over two years. Other costs associated with pulling, well cleanout, and the lost revenue created by downtime were also eliminated. As a result, the operator's payout for the ClO2 treatment was less than 30 days. Other ESP problem wells were then treated with equal success.

The Science behind ClO2

Unlike alternative technologies, chlorine dioxide is a true gas that is a relatively stable oxidant, reacting only with reduced compounds such as sulfides, phenols, and biomass. Additionally, chlorine dioxide kills both active and inactive bacteria, unlike conventional biocides. Chlorine dioxide has also been shown to kill bacterial spores with relatively low contact times, and bacteria cannot build resistance to chlorine dioxide. It is also a well-established EPA-registered biocide for use in the drinking water and food industries.

Case Studies

Oil Field Case Study: Reducing Pressure on Water Injection Wells

ClO2 Treatment Process

Oil Fields

The Issue: Reducing Injection Pressure

The Solution: Treatment using chlorine dioxide (ClO2) stimulation process

Background

Annual stimulation was performed on a west Texas well to reduce injection pressure.

Chlorine Dioxide Application Considerations

Well Data	
Well type:	Water flood injection
Porosity:	8.5%
Perforations:	350 ft (gross), 87 ft (net)
Plugging Agent:	FeS and $CaCO_3$

Duration (days)	BWPD	Pressure (psi)
10	230	3000
50	210	3300
80	200	3400
135	200	3450

Before the last conventional acid stimulation, water was injected at a rate of 200 bpd and injection pressure was 3450 psi.

The acid stimulation similar to those from previous years produced the following results:

The well returned to pre-stimulation volume and pressure within 135 days of the treatment. Because of the less than satisfactory performance from the stimulation, the customer wanted to consider alternatives in an effort to enhance longevity.

During a conventional acid stimulation, the acid solubilizes iron sulfide and calcium carbonate. As fluid pH rises, iron sulfide precipitates again, plugging the pore spaces. The result is reduced injection volume and increased injection pressure.

Chlorine Dioxide Treatment Approach

ClO2 stimulation service for onsite generation of chlorine dioxide was recommended to treat the problem. When properly staged during a well stimulation with acid, chlorine dioxide will convert the iron sulfide to water-wet hydrous ferric oxide which is then chelated by additives in the acid. The iron sulfide will not precipitate again.

It was also recommended that a micellar acidizing solvent be used in conjunction with the acid. The micellar acidizing solvent is completely miscible in conventional acids, converting the acid to a more powerful solvent by combining detergency, water-wetting and solvent properties into a single treating fluid.

Results

The treatment consisted of 200 barrels of ClO2 along with 110 gallons of micellar acidizing solvent added to the acid stage. The following results were achieved:

The customer's expectations for this treatment were far exceeded. Not only was the well pressure reduced by more than 1000 psi, injection volume increased by 75 percent. Even four years after the completion of treatment, the well did not require additional stimulation. This translated into substantial cost savings and increased profit for the customer as a result of less frequent acidizing and reduced operating costs.

Duration (days)	BWPD	Pressure (psi)
10	340	1850
50	350	2000
80	340	1860
135	350	2100
1397	350	2400

Study Case

Increase Oil and Gas Well Production

ClO2 Treatment Process

Oil Fields

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The Issue: Bacteria and Iron Sulfide Plugging

The Solution: Treatment using chlorine dioxide (ClO_2) stimulation process

Background

A Denver-based oil and gas company operated a large oil and gas field in north central Utah. The producer had a history of bacteria and related iron sulfide problems.

Chlorine Dioxide Application Considerations

Oil and gas production was down to an average of 31 BOPD, with dark FeS streaks. The well had been treated with various conventional biocides. These conventional biocides were unable to eradicate the sulfide problem that had built up in the well and, therefore, it was necessary to find an alternative solution.

Chlorine Dioxide Treatment Approach

A complete study of the producer resulted in the recommended use of chlorine dioxide treatment. ClO_2 is staged with acid containing micellar solvent, corrosion inhibitor and iron chelant.

In conventional acid stimulation the acid solubilizes carbonate and iron sulfide which remains in solution as long as the pH remains below 2. Once the acid is spent and the formation fluid pH rises above 2, the iron sulfide re-precipitates, plugging the pore spaces.

The ClO_2 process enhances conventional acid stimulation by oxidizing the preferentially oil-wet hydrous ferric oxide which is then chelated by additives in the acid, and insoluble sulfide to water-soluble sulfate. Chlorine dioxide also has the ability to oxidize biomass and polymer damage.

1000 bbls of ClO_2 staged with 15% HCl acid were pumped down the tubing after removing the pump. The well was shut in for one day after treatment before being brought back in production.

After treatment with ClO_2 the well was clean, producing yellow crude with no sign of FeS in the production. Gas production went from 76 MCF/D before the treatment to 188 MCF/D. Oil production went from 29 BOPD before treatment to 89 BOPD after the job.

Results

The ClO_2 treatment was successful. Over a 90 day period after the treatment the production revenue was approximately $150M, (an ROI of 301%), compared to revenue of about $50M if the field had elected not to complete the ClO_2 treatment. The payback period for this field was 27 days. After 90 days the field was still producing at the higher rate.

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Case Studies

Oil Field Case Study: Control Bacteria in Oil and Gas Wells

ClO2 Treatment Process

Oil Fields

The Issue: Bacteria in Oil and Gas Wells

The Solution: Treatment using chlorine dioxide (ClO2) stimulation process

Background

A Texas-based oil and gas company operated nine producing and five saltwater disposal wells in eastern Utah. Over time, the field became progressively sour as a result of contaminated water used in completion and workover fluids.

Chlorine Dioxide Application Considerations

The company's producing wells generated 160 ppm H_2S in the gas phase and +/- 5 ppm of soluble sulfide in the water phase, with active sulfate reducing bacteria growth throughout the field. The producer had a history of bacteria, (10^3 counts), and related problems, including H_2S levels in the range of 80-90 ppm in the produced gas. The wells had been treated with various conventional biocides. These conventional biocides were unable to eradicate the sulfide problem that had built up in the wells and, therefore, it was necessary to find an alternative solution.

Chlorine Dioxide Treatment Approach

A complete study of the producer resulted in using chlorine dioxide. ClO2 was staged with acid containing micellar solvent, corrosion inhibitor and iron chelant.

In conventional acid stimulation the acid solubilizes carbonate and iron sulfide which remains in solution as long as the pH remains below 2. Once the acid is spent and the formation fluid pH rises above 2, the iron sulfide re-precipitates, plugging the pore spaces.

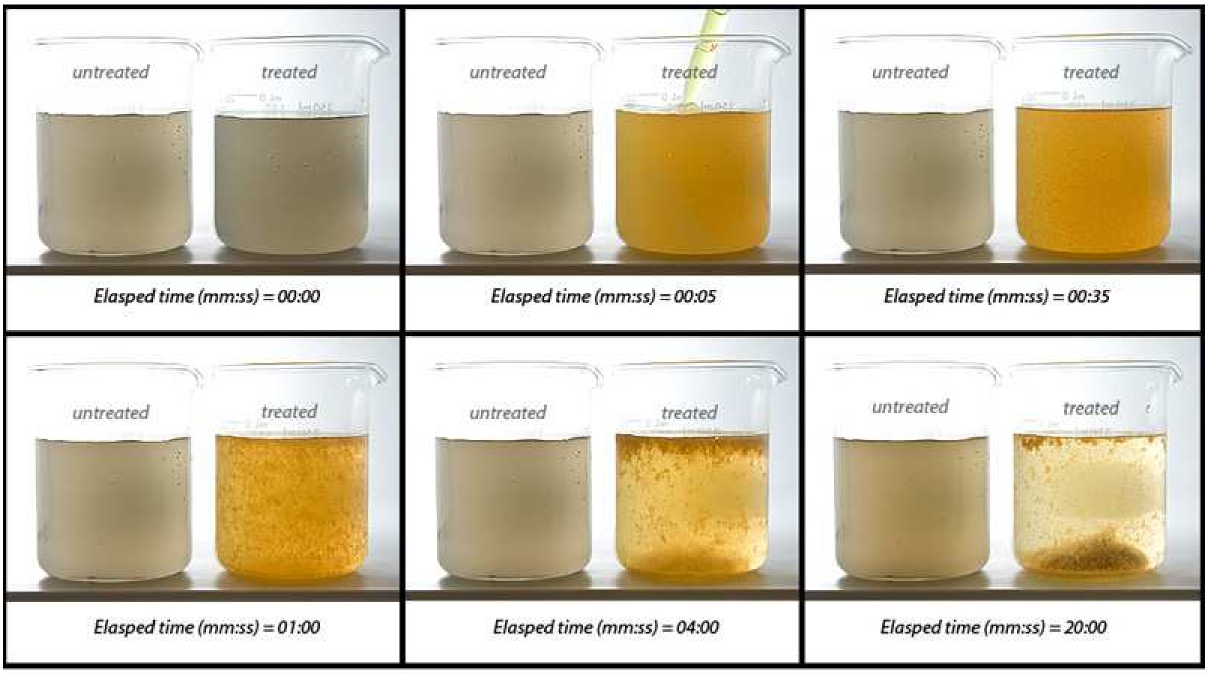
	BOPD	Bacteria Count	H_2S (ppm)
Before	25-30	10^3	80-90
After	50-55	0	0
1 Month	50-55	0	0
2 Months	40	0	0
6 Months	25-30	0	0
1 Year	25-30	0	0

The ClO2 treatment enhances conventional acid stimulation by oxidizing preferentially oil-wet sulfide to form water-wet hydrous ferric oxide which is then chleated by additives in the acid, and insoluble sulfide to water soluble sulfate. ClO2 also has the ability to oxidize biomass and polymer damage.

Results

100 bbls of ClO2 staged with 7.5% HCl acid was pumped through the coiled tubing to displace the volume of fluid in the hole with ClO2. The coiled tubing, along with a wash tool were then moved across the perforations to increase the coverage of the treatment. The well was shut in for one day after treatment before being brought back in production.

WATER MANAGEMENT



Chlorine Dioxide Application to
Oil and Gas Process Water

Case Studies

Oil Field Case Study: Increase Wastewater Disposal Well Injection Rate

ClO2 Treatment Process

Oil Fields

The Issue: Bacteria in Oil and Gas Wells

The Solution: Treatment using chlorine dioxide (ClO2) stimulation process

Background

A Texas based oil and gas company operates a gas processing facility in Southeastern New Mexico. 700 barrels (bbls) of wastewater per day are produced at the facility and pumped to a disposal well in the San Andres formation.

Chlorine Dioxide Application Considerations

The disposal well continually plugged and periodic acidizing was used in an attempt to restore the injection rate to at least a 700 BPD rate. Numerous acid treatments over a two-year period did not restore the well to the necessary 700 BPD level, or maintain improvement for an extended period of time. After acidizing, the injection rate would be down to a 300 BPD level within two months.

The operator installed a 15,000 bbl storage tank to hold the excess wastewater when the injection rate fell below 700 BPD. In addition, a 52-cartridge filter system was installed in an attempt to upgrade the disposal water quality. Despite these system modifications, plugging continued to be a serious problem. The storage tank eventually filled up, requiring the removal of excess water by truck at an annual cost over $50,000. Filter maintenance proved to be equally costly at approximately $30,000 per year.

Chlorine Dioxide Treatment Approach

A complete study of the wastewater stream and the disposal well was initiated, which resulted in the recommended use of ClO2 treatment. ClO2 is staged with acid containing micellar solvent, corrosion inhibitor and iron chelant.

The ClO2 treatment enhances conventional acid stimulation by oxidizing preferentially oil-wet sulfide to form water-wet hydrous ferric oxide which is then chelated by additives in the acid, and insoluble sulfide to water soluble sulfate. Chlorine dioxide also has the ability to oxidize biomass and polymer damage.

Results

A treatment of 100 bbls of ClO2 staged with an acid containing micellar solvent, corrosion inhibitor and iron chelant was required to stimulate the well, which cost significantly less than the operator’s current program.

Immediately after the ClO2 treatment, injection rates exceeded 1,500 BPD. The storage tank was emptied and the injection pump was able to inject the 700 bbls in just 12 hours.

The job was a complete success and the excellent injection rates continued for 3.5 years, saving the operator approximately $80,000 annually. Recently, a plant turn-around caused considerable debris to be sent to the well and it plugged. The operator authorized a second stimulation using 150 bbls of ClO2 which returned the well to an injection rate in excess of 1,500 BWPD, where it has remained.

Study Case

Oil Field Study Case: Maximizing Frac Water Reuse with Chlorine Dioxide

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Treating Frac Water

Oil Fields

The Issue: Hydraulic Fracturing (Frac) Water Reuse

The Solution: Treatment with ClO2

Background

A Rocky Mountain Oil producer was experiencing difficulty in reuse of fracturing fluids due to high contaminant and bacterial loading. Friction reduction and other fracturing chemical additive use rates were high or unfeasible because of the high contaminant levels. Disposal costs, fresh water costs, and water use concerns were severely impacting fracturing operations. High residual polymer levels and solids loading were contributing to high hydrogen sulfide production in the pits, causing safety and environmental concerns.

Chlorine Dioxide Application Considerations

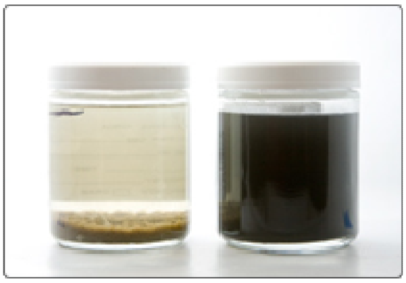
Chlorine dioxide is an oxidizing biocide that has been used for municipal water disinfection in the United States since the 1940's. It is used in the food industry as a direct food contact and incidental food additive status sanitizer and disinfectant for the vegetable, meat, dairy, and fresh pack sectors. It also has been widely used for the disinfection of municipal water wells and for the control of microorganisms in potable water aquifer replenishment injection wells. Globalex has extensive experience using chlorine dioxide for the environmental clean-up of contaminated industrial pits, lagoons, rivers, bays, lakes and buildings. The benefits for the use of chlorine dioxide in these industries are that chlorine dioxide provides superior penetration into biomass combined with superior microbial kill, while also preventing the formation of undesirable disinfection by-products such as THM's (from chlorine or bleach) and bromates (from ozone or hydrogen peroxide). Based on the company's experience with chlorine dioxide in these and other industries, Globalex developed a treatment approach.

Chlorine Dioxide Treatment Approach

Globalex uses the same treatment approach for Oilfield pits and lagoons that it had pioneered for the treatment of Algae contamination of municipal drinking water impound lakes and lagoons. ClO2 treatment was applied to the water to be used for hydraulic fracturing by pre-treatment of the fluid in the storage pits and tanks. Using drive water from the pit, a ClO2 generation system with a maximum capacity of 24,000 lbs. per day continuous production was set up at the location. This system is self-contained and has a distribution system that allows it to circulate fluids in the pit or tank. The hydraulic fracturing fluid was circulated through the chlorine dioxide system and treated in situ until the contaminants were oxidized and a slight (less than 0.1 mg/l) residual of chlorine dioxide was established in the pit. In this application, the fluids then were allowed to stand in the pit for four hours, the solids were allowed to settle and free oil was skimmed from the pit prior to commencement of fracturing.

Results

The immediate benefit of the chlorine dioxide treatment was the elimination of hydrogen sulfide off-gassing from the pits. Oxidation of the fluid allowed the separation of the solids and hydrocarbons from the water. The picture shows the typical effect of chlorine dioxide on water taken from a contaminated pit. The untreated water (right) is from a contaminated pit. The same water treated with chlorine dioxide is on the left (after about 15 minutes) and clearly shows solids precipitated on the bottom, a thin oil layer on the top and clear water in between.



The water was tested for use for fracturing and found to require additive levels close to those required by fresh water for fracturing. This producer has been able to eliminate water disposal due to unsuitability and minimize make up water purchases. Additionally, fracturing fluids have been able to be stored for future use without environmental concerns due to hydrogen sulfide off-gassing and odors.

Study Case

Oil Field Case Study: Disinfecting Water for Well Fracturing with Chlorine Dioxide

Treating Frac Water

Oil Fields

The Issue: Frac Water Reuse

The Solution: Treatment with ClO2

Background

A Mid Continent Oil producer was experiencing disinfection and permitting difficulties using conventional Oilfield biocides. High bacterial loading and short contact times required the use of high dosages of conventional biocides that were both costly and of concern to the regulatory community.

Chlorine Dioxide Treatment Approach

Chlorine dioxide was applied to the water to be used for well fracturing in much the same way as it would be for primary disinfection of municipal drinking water, or for pre-treatment of potable water aquifer injection wells. A ClO2 generation system with a maximum capacity of 24,000 lbs. per day continuous production was set up on the location. This system has nearly infinite turn-down capability due to the incorporated dosage pump system that can feed four points independently at rates from 0.02 to 2.5 lbs. chlorine dioxide per minute each. Chlorine dioxide dosage rates and residual values are monitored within the control cabin of the unit. Water was pumped from a small reservoir that contained some agricultural run-off to a series of frac tanks set up on location at a rate of 110 bbl per minute. Prior to start up, the chlorine dioxide demand of the water was determined and the water was tested for sulfate reducing (SRB) and general aerobic bacteria (GAB). The demand was found to range from 12 to 15 mg/l and SRB and GAB levels were found to be 105 and 104 cfu/ml, respectively. Chlorine dioxide was added at such a rate as to achieve a residual of 0.5 to 1 mg/l. Residual was monitored on 15-minute intervals throughout the stage. Residence time for the chlorine dioxide treated water in the frac tanks was approximately 15 minutes. Analysis was also performed on grab samples of the treated water for SRBs and GABs.

Results

Chlorine dioxide residuals were maintained throughout the process between 0.4 and 0.9 mg/l. There was no growth on SRB and GAB samples collected throughout the process. Reports from the producer have indicated significantly less occurrence of hydrogen sulfide production from wells fractured with chlorine dioxide-treated water than those treated with conventional biocides-while over 50% of the conventional biocide-treated wells experienced hydrogen sulfide production within 12 months, no chlorine dioxide-treated wells reported hydrogen sulfide production within 12 months of fracturing.

Study Case

Municipal Water Well Case Study: Use of Chlorine Dioxide to Restore Municipal Potable Water Wells

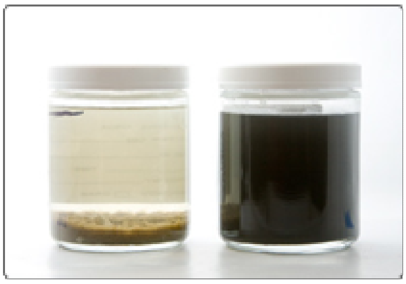
Treatment Results

Municipal Water Wells

The Issue: Restoration of Municipal Water Wells

The Solution: Treatment with ClO2

Background



A major Southern California municipality servicing a population of over 100,000 uses potable water source wells to supplement its surface water supply of drinking water. The wells began experiencing high bacteria levels, sulfur odors, and reduced production capacities. The primary problem identified was bacterial fouling and biomass accumulation in the wells. The municipality attempted remedial treatments with sodium hypochlorite and hydrogen peroxide. While initial flow-back results were promising, bacterial contamination levels equivalent to pre-treatment were observed within a few days. Additionally, no improvement was seen in the production capacity of the wells. Some of the wells had experienced up to a seventy percent decline in productivity while retaining the original rest water levels in the well, indicating severe fouling.

Chlorine Dioxide Treatment Approach

Chlorine dioxide was applied to the wells in much the same way as had been used for bleach, chlorine and hydrogen peroxide. First the well was pumped down as far as possible with the pump, and then sufficient chlorine dioxide was applied to the well to treat a five-foot radial volume from the water-producing zone at a concentration of 1500 mg/l chlorine dioxide. On wells that demonstrated significant hard water scaling, acetic or citric acid was applied with the chlorine dioxide to help dissolve inorganic carbonate scale deposits. Once the well was loaded with chlorine dioxide, the well casing was displaced to the static water level three times with fresh water containing five milligrams chlorine dioxide to prevent re-contamination of the well. After the wells were displaced, they were shut in for four hours to allow time for the acid to react and the chlorine dioxide to dissipate. The wells were then pumped off for a total of three treatment volumes to a temporary holding tank, and then put back on normal operation once normal pH values and residual oxidants were verified.

Results

A single chlorine dioxide treatment achieved a 100 percent success rate for the sustained elimination of microbial contamination in the wells, as compared to a less than fifty percent success rate for the alternatives. Additionally, chlorine dioxide-treated wells averaged a recovery rate of 143 percent of original drilled production value compared to 54 percent for alternative technologies.