Treating High Concentrations of Perchlorate in Groundwater Using a Two-Stage Advanced Bioreactor Design

A. PAUL TOGNA AND MICHAEL DELVECCHIO, Shaw Environmental & Infrastructure, Inc., Lawrenceville, New Jersey

TODD WEBSTER, Shaw Environmental & Infrastructure, Inc., San Diego, California

BOB HINES, USFilter, Envirex Products, Waukesha, Wisconsin

MARY CHEUNG, Veolia North America Operations Support, Solon, Ohio

L. KEITH BAILEY, Kerr-McGee Shared Services LLC, Oklahoma City, Oklahoma

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ABSTRACT: Kerr-McGee Chemical has installed a pumping system coupled to a biological treatment plant in Henderson, Nevada to remove perchlorate from groundwater impacting Lake Mead. This plant, which utilizes two trains of biological fluidized bed reactors in series, successfully completed a 35-day performance test in November 2004 at approximately 93 percent of the system's maximum design load.

INTRODUCTION

Manufacture of perchlorate compounds began at the Henderson site in 1945 in facilities owned by the U.S. government. The U.S. Navy expanded production significantly in 1953, when it completed construction of a plant for the manufacture of ammonium perchlorate. The Navy continued to own the ammonium perchlorate plant as well as other associated production equipment at Henderson until 1962, when the plant was purchased by a predecessor of Kerr-McGee Chemical.

Kerr-McGee Chemical began decommissioning the facility and remediating associated perchlorate contamination, including surface impoundments and groundwater when it decided to exit the business in 1998. In 1999, they started removing perchlorate from the groundwater near the Las Vegas Wash using a pumping system coupled to ion exchange technology. In 2001, the company installed additional wells, pumping systems and additional ion exchange capacity to capture and treat additional water near the perchlorate manufacturing sources. Kerr-McGee Chemical initiated the design of a biological treatment process in December 2002. This plant began startup operations in January 2004.

The biological treatment process involves the use of two trains of fluidized bed reactors (FBRs) in series. The FBR is a highly efficient fixed-film reactor that utilizes stationary microbes on a hydraulically fluidized bed of media particles. These particles provide a vast surface area for biological film growth. Sand is used as the fluidized bed media in the front train of four FBRs (each 14 feet in diameter and 30 feet in height), while carbon is used in the back train of four FBRs (14 feet in diameter and 26 feet in height). Perchlorate laden water is introduced to the front train of four FBRs, operated in parallel, at a total flow-rate of 1,000 gallons per minute (gpm), with an upper inlet perchlorate concentration of 400 parts per million (ppm). Chlorate and nitrate also are present in the feed water. An electron donor (ethanol) is pumped into each of the front-train FBRs where it is utilized in anoxic biological reduction processes. The by-products of the processes are chloride ions, heat generation and additional biomass. All water from the front train of FBRs, along with any biomass that is separated from the media, combines together and enters the back train of four FBRs operated in parallel. In these reactors, any remaining concentration of perchlorate is further biologically treated to meet all regulatory discharge limits. Contaminant free water from the back train of FBRs proceeds through an aeration system, two dissolved air flotation units and an ultraviolet ray disinfection system, before being released to the Las Vegas Wash. Solids recovery and filter press systems also are employed at the plant.

The FBR plant successfully completed a 35-day composite sampling performance test on November 6, 2004 at approximately 93 percent of the system's maximum design load. During the test all design water quality effluent conditions were met. Operation of all of the components of the plant, as well as performance results, will be discussed in the sections below.

BIOLOGICAL PERCHLORATE REDUCTION

Perchlorate reduction is an anoxic process (i.e. occurs only in the absence of oxygen) which produces two innocuous products - chloride and oxygen (Rikken, Kroon, and van Ginkel, 1996). Several microbial strains have been isolated with the ability to degrade perchlorate by using the molecule as an electron acceptor during growth on either an inorganic or organic substrate. This is similar to the facultative metabolism observed in natural systems where the amount of oxygen is variable; as the dissolved oxygen decreases, other compounds, including nitrate, iron, sulfate, and eventually carbon dioxide, are utilized as the terminal electron acceptor. An appropriate substrate (i.e. electron donor) must be supplied to the microorganisms in an amount sufficient to reduce all of the residual oxygen, nitrate, nitrite and chlorate present before perchlorate reduction can proceed. Methanol, ethanol, a mixture of ethanol and methanol, and acetate (acetic acid) have been investigated as growth substrates for perchlorate treatment in FBRs; during these studies, only methanol alone failed to support efficient perchlorate reduction (Sutton and Greene, 1999). Several other substrates, including lactate, propionate, citrate, hydrogen gas, molasses, sucrose, and vegetable oils will also support perchlorate reduction (Hatzinger, 2005).

PERCHLORATE REDUCTION USING BIOLOGICAL FLUID BED REACTORS

Biological FBRs are fixed-film bioreactors that rely on the immobilization of microbes on a hydraulically fluidized bed of small media particles (see Figure 1). Due to the relatively thin films obtained, the FBR maintains high concentrations of active biomass in the reactor, thereby providing high volumetric efficiency. The influent stream is introduced in an up-flow mode at a velocity sufficient to fluidize, or expand, the bed of media particles. The most frequently used media are sand and granular activated carbon (GAC). Sand is usually chosen for treatment of water containing high concentrations of organics or where the equivalent organic dosing is high, and the inventory of biomass in the FBR is expected to be large (i.e., high biofilm growth applications). GAC is usually selected when the treatment criteria is very stringent (i.e., treatment down to μg/L levels), or for polishing the effluent from sand FBR systems.

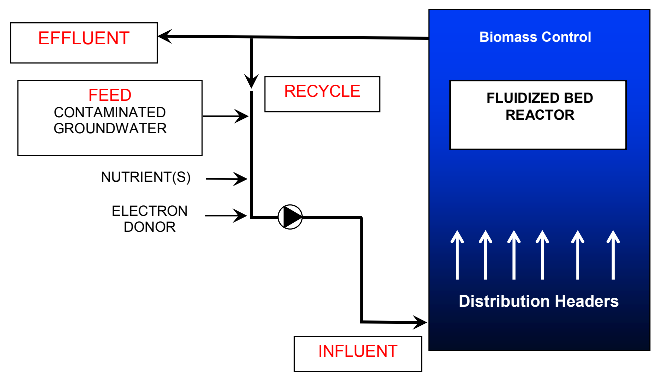

Figure 1. Anoxic FBR Process Flow Diagram

The basic components of an anoxic FBR system include the bioreactor, the media, a fluid distribution system in the bottom of the reactor, feed and influent pumps, nutrient/supplement addition systems, a pH control system, and a biomass growth control mechanism.

Currently, there are five full-scale FBR systems that have been installed in the United States to treat perchlorate-contaminated groundwater (see Table 1). All of these systems are treating the perchlorate in the feed to required effluent discharge limits.

HENDERSON SITE BACKGROUND AND HISTORY

PLANT HISTORY – Manufacture of perchlorate compounds began at the Henderson site in 1945 in facilities owned by the U.S. government. The U.S. Navy expanded production significantly in 1953, when it completed construction of a plant for the manufacture of ammonium perchlorate. The Navy continued to own the ammonium perchlorate plant as well as other associated production equipment at

Table 1. FBR Installations Treating Perchlorate-contaminated Groundwater

Client/Owner	Location	Number of Reactors [1]	Size (Each Reactor)	Year Installed	Design Water Flow (gpm)	Design Composition [2]
GenCorp Aerojet	Rancho Cordova, CA	4 - GAC [3]	14' Dia. x 21' Height	1998	4,000 (currently operating at 6,000)	3 to 6 mg/l ClO_4^- 1.5 mg/l NO_3-N
U.S. Army Corps of Engineers	Longhorn Army Ammunition Plant, Karnack, TX	1 - GAC	5' Dia. x 21' Height	2000	50	15 mg/l ClO_4^- 2 mg/l NO_3-N
U.S. Navy	McGregor, TX	1 - GAC	7.5' Dia. x 21' Height	2001	100 400	8.8 mg/l ClO_4^- [4] 7.2 mg/l NO_3-N [4] 3.5 mg/l ClO_4^- [5] 1.5 mg/l NO_3-N [5]
Kerr-McGee Chemical	Henderson, NV	4 - Sand [6] 4 - GAC [6]	14' Dia. x 30' Height [7] 14' Dia. x 26' Height [8]	2003	1,000	≤ 400 mg/l ClO_4^- ≤ 500 mg/l ClO_3^- ≤ 50 mg/l NO_3-N
NASA - Jet Propulsion Laboratory	Pasadena, CA	1 - GAC	11.5' Dia. x 24' Height	2004	250	3.6 mg/l ClO_4^- 11.5 mg/l NO_3-N

Notes:

1. GAC = FBR containing granular activated carbon media; Sand = FBR containing sand media.
2. ClO_4^- = perchlorate; ClO_3^- = chlorate; NO_3-N = nitrate as nitrogen.
3. Four FBRs operated in parallel, each receiving 1,000 gpm of flow.
4. Design condition for 100 gpm.
5. Design condition for 400 gpm.
6. Flow is through four primary sand FBRs operated in parallel followed by polishing in four secondary GAC FBRs operated in parallel.
7. Size is for sand FBRs.
8. Size is for GAC FBRs.

Henderson until 1962, when the plant was purchased by a predecessor of Kerr-McGee Chemical. The ammonium perchlorate produced at the Henderson facility was used primarily in federal government defense and space programs. Perchlorate has been detected in nearby Lake Mead and the Colorado River.

Kerr-McGee Chemical began decommissioning the facility and remediating associated perchlorate contamination, including surface impoundments and groundwater when it decided to exit the business in 1998. In 1999 and 2001, the company enetered into consent orders with the Nevada Division of Environmental Protection (DEP) that require the company to implement both interim and long-term remedial measures to capture and remove perchlorate from groundwater. In 1999, Kerr-McGee Chemical initiated interim measures and started removing perchlorate from the groundwater in near the Las Vegas Wash using a pumping system coupled to ion exchange technology. In 2001, the company installed additional wells, pumping systems and additional ion exchange capacity to capture and treat additional water near the perchlorate manufacturing sources. Kerr-McGee Chemical initiated the design of a biological treatment process in December 2002. This plant began startup operations in January 2004.

CONTROL STRATEGY – The groundwater enters the Colorado River through the Las Vegas Wash, which feeds into Lake Mead (and subsequently supplies the Colorado River; see Figure 2). The Kerr-McGee Chemical plant is approximately three miles south of the Las Vegas Wash.

A series of wells was installed to capture the plume in three different locations:

- Las Vegas Wash ("Seep wells")
- Athens Road
- On-site Wells (high concentration "source" containing chromium)

An on-site slurry wall was installed to cut off the high concentration plume from further migration. In order to move and ultimately treat the water, 42,000 feet of buried pipe was installed to convey all the well water back to the Kerr-McGee Chemical plant for treatment and to convey treated water back to the Las Vegas

Wash. This piping system included three pump stations in order to maintain flow to the plant. At the company's plant, an 11-acre, 60 million-gallon pond was constructed to act as temporary storage and evaporation for the post chrome-treated on-site wells. Lastly, an equalization area was installed to combine all the well sources into a single flow for treatment.

INITIAL TREATMENT – Along with all the collection, conveying and equalization equipment, a temporary ion exchange system was installed to treat the collected water until a permanent treatment technology could be chosen and a plant built. This temporary system treated the lower concentration water from the Seep and Athens Road wells. Water from the on-site wells was treated for chromium removal and then stored/evaporated in the on-site 11-acre pond.

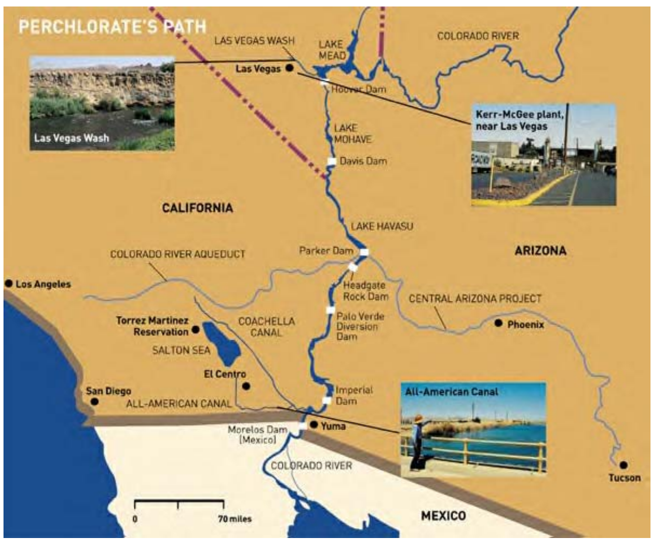

Figure 2. Perchlorate Path down the Colorado River (Courtesy of Chemical & Engineering News)

PERCHLORATE FBR TREATMENT SYSTEM

DESIGN CONDITIONS – Table 2 represents the influent design parameters for the biological FBR treatment system after combining the three well sources. Table 3 shows the required effluent parameters after treatment.

TREATMENT SYSTEM DESCRIPTION OVERVIEW – The treatment plant takes its feed from an equalization facility. The major unit operations/treatment vessels are as follows (see Figure 4):

1. Four (4) first-stage fluidized bed reactors – 14 ft. diameter X 30 ft. straight side with sand media (FBRs 1, 2, 3, and 4);
2. Two (2) first-stage separation tanks – 14 ft. diameter X 30 ft. overall height (T-2011 and T-2012);
3. Four (4) second-stage fluidized bed reactors – 14 ft. diameter X 26 ft. straight side with granular activated carbon media (FBRs 5, 6, 7, and 8);
4. Two (2) second-stage separation tanks – 14 ft. diameter X 26 ft. overall height (T-3011 and T-3012);
5. One (1) aeration tank – 14 ft. diameter X 24.5 ft. straight side (T-401);
6. Two (2) dissolved air flotation (DAF) vessel assemblies – 10.5 ft. W X 10.5 ft. H X 40 ft. overall length (D-501 and D-551);
7. One (1) ultraviolet (UV) disinfection system (X-621);
8. One (1) gravity thickener – 20 ft. diameter X 18 ft. straight (T-602);
9. Two (2) filter press assemblies, 80 cu. ft. each (X-901 and X-902).

Table 2. FBR System Design Influent Conditions

Parameter	Units	Value
Perchlorate	ppm	≤ 400
Chlorate	ppm	≤ 500
Nitrate (as N)	ppm	≤ 50
Chloride	ppm	≤ 2,500
Total Dissolved Solids	ppm	≤ 10,500
Flow Rate	gpm	950 (Design Average) 1,000 (30-day Average)

Table 3. System Design Effluent Conditions and 35-day Performance Test Results

Parameter	Units	Value
Perchlorate	ppb	≤ 18 [a]
Ammonia (as N)	lb/day	≤ 20
Total Phosphorus	lb/day	≤ 20
Total Suspended Solids	ppm	≤ 135
Biochemical Oxygen Demand	ppm	≤ 25
pH	s.u.	6.5 - 9

Note: [a] as per Kerr-McGee Chemical's NPDES permit

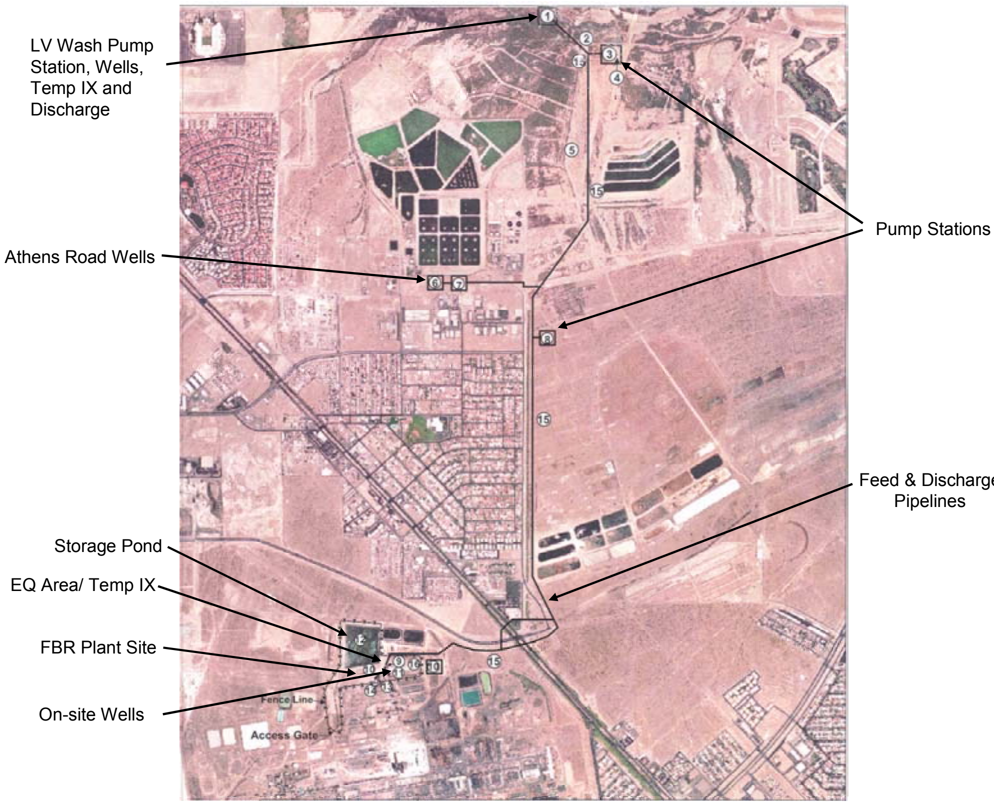

Figure 3. Overall System Map

MAIN FEED STREAM TREATMENT – The system is designed to accept feed water at up to 1,000 gpm maximum hydraulic loading. Equalized feed enters the system at the two first-stage fluidization pump skids. Individual flow control valves control feed flow splitting to each of the operating first-stage FBR vessels. Under normal steady state operating conditions, the total feed flow is equally split among the operating first-stage FBR vessels. It is, however, possible to operate with unequal flow splitting or with one of the first-stage FBRs off-line.

The system controls provide the ability to set the system feed flow at a constant rate or to control feed flow based on maintaining level in the equalization tanks. A trace element solution is metered into the system feed. The mixture is fed into the feed stream from a separate tank using a metering pump.

First-Stage FBR Treatment. Feeds to each operating first-stage FBR vessel are combined with recycle flow, ethanol, nutrients solution and pH control solution (i.e., 25% caustic). The caustic and ethanol solutions are, respectively, controlled by pH and optional ORP control systems. The ethanol flow may also be automatically controlled individually to each FBR in proportion to the feed flow to each FBR, which is the typical mode of ethanol flow control. Nutrient solution flow is controlled to each FBR in proportion to the feed flow to each reactor. The FBR vessels contain integral fluidization distribution and effluent collection systems. These internal components are designed to enhance uniform flow distribution. Microorganisms metabolize the ethanol solution and utilize the perchlorate, chlorate, nitrate and oxygen contained in the feed water. These are converted to harmless minerals in the process. The microbes form a film on the fluidized sand media.

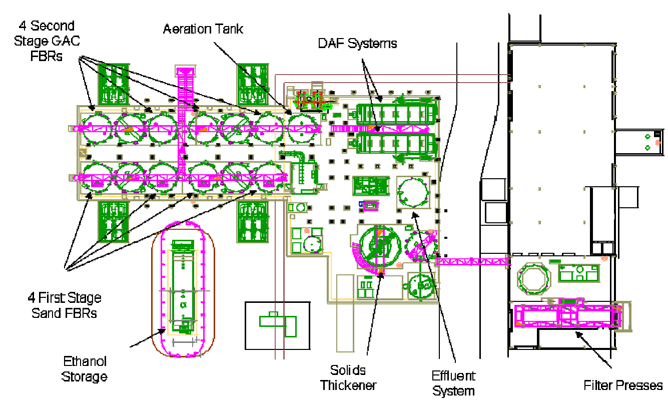

Figure 4. Treatment Plant Plan View

As with virtually all biological processes, an excess biomass byproduct is produced. As biomass accumulates on the FBR media, the fluidized bed height expands. Some excess biomass is removed by the shear that is caused by the normal flow through the bed. Additional excess biomass is removed from the fluidized beds by operation of the Bed Height Control Pumps. These pumps are intended to operate continuously, taking suction from the top of the FBR media bed at the control bed height. The pumping action and flow through a throttling pinch valve at the pump discharge provide sheer to remove excess biomass from the pumped media. The separated biomass exits the FBR vessels with the effluent and recycle streams.

The biomass control system also includes provisions for removal of excess biomass from a lower level within the fluidized bed. This system is operator-controlled based on the measured FBR bed height.

Media Separation. First-stage FBR effluent flows to centrifugal cone bottom separator vessels. These vessels are designed to capture any media in the first-stage effluent and recycle streams. The media return pumps operate on an automated cyclical basis to transfer captured media back to the FBR vessels. The bulk of the water entering the first-stage separators is returned to the first-stage FBR vessels as recycle. The balance of the water that enters the separators vessel exits to the second stage. First-stage treated effluent is removed from the first-stage system through level control valves that maintain the separators' water levels at the design set points.

Second-Stage FBR Treatment. Flow from the first-stage system is typically equally split among the four second-stage FBR vessels. The second-stage FBR vessels contain granular activated carbon (GAC) media. Internal components include a fluidization flow distribution system, recycle and effluent collection systems, biomass separators and an "in-bed biomass control system". The biomass separators include provisions for collection and removal of separated excess biomass. This stream flows to the thickener by gravity at an operator-adjustable flow.

Second-Stage Separators. Second-stage FBR effluent flows to centrifugal cone bottom separator vessels. These vessels are designed to capture any media in the second-stage effluent and recycle streams. Media return pumps transfer captured media back to the FBR vessels. The bulk of the water entering the second-stage separators is returned to the second-stage FBR vessels as recycle. The balance of the water that enters the separator vessels exits to the aeration vessel.

Aeration. Nitrate, chlorate and perchlorate are all reduced to effluent design concentrations in the effluent of the second-stage FBRs. This stream flows to the aeration tank where fine bubble aeration is used to approach saturation concentrations of dissolved oxygen. The benefits of this aeration process include a reduction in the amount of high-pressure air required in the downstream DAF system, residual oxygen in the water for discharge, and partial oxidation of trace amounts of reduced sulfur that may be present in the second-stage FBR effluent. The air effluent from the aeration tank passes through two biofilters prior to discharge to the atmosphere.

Dissolved Air Flotation (DAF). Aerated water flows to the two DAF systems. The systems are operated in parallel. Flocculation is further enhanced by use of ferric chloride coagulant and a polymer solution that are metered into the liquid upstream of the DAF vessel(s). Coagulant and polymer flows are controlled in proportion to the total system feed flow as measured by the first-stage FBR flow meters.

Float material is collected by a skimming mechanism that conveys the skimmed solids stream into a compartment within the DAF vessel(s). The accumulated skimmed solids are removed by automated cyclical operation of DAF float pumps. All float and settled solids are pumped to the thickener for further gravity dewatering.

Effluent Disinfection. DAF effluent flows by gravity into the effluent tank. From there it is pumped through a UV disinfection system, and is discharged under pressure through the effluent pipeline back to the Las Vegas Wash.

SECONDARY STREAMS – The secondary streams from the system include those feeds to the solids handling unit operations. These unit operations are the thickener, the solids conditioning tank, and the filter presses.

Thickener. The thickener receives the excess biomass stream from the second-stage FBRs and the float and underflow streams from the DAF float pumps. Thickener feed enters a central flocculation zone or detention hood within the thickener. Flocculation is enhanced within the detention hood by variable speed flocculation mixers and provisions for polymer solution feed. Clarified liquid is pumped to the aeration vessel. Settled solids accumulate in the lower section of the thickener. This gravity-thickened stream is periodically pumped out by the thickener underflow pump to the solids conditioning tank and filter presses for further dewatering, or optionally to a truck loading connection for removal as a liquid suspension.

Solids Conditioning and Filter Press. The two filter presses operate as a batch system on a schedule established by the system operators. It is generally preferable to operate both presses in parallel during the batch process.

A predetermined volume of thickener underflow is pumped from the thickener to the conditioning tank. Ferric chloride solution and powdered lime from the hydrated lime storage silo are also added sequentially to the conditioning tank at predetermined dosages. The conditioning tank agitator mixes the suspension. The conditioned suspension is pumped to the filter presses during the press operation cycle. Filtrate flows by gravity from the presses to the filtrate tank. This filtrate is recovered periodically by automated pumping from the filtrate tank to the aeration vessel.

CHEMICAL FEED SYSTEMS – The system has a number of chemical feeds that are fed to specific unit operations based on a measured control parameter and a PLC-based feedback control loop, or based on the flow into that unit operation using a proportionality constant.

Trace Elements. A trace elements mixture is added to the feed to optimize the performance of the system. The mixture is fed into the feed stream from a separate tank proportional to the feed flow rate.

Caustic Soda. Caustic soda is used for pH control within the FBRs. Eight electric operated diaphragm metering pumps are used to pump the caustic to each of the eight FBRs. The caustic soda flow to each FBR is controlled by pH sensors located in each FBR influent (i.e. combined feed and recycle) line.

Polymers. Both the DAFs and the sludge thickener use polymers for assistance in separating solids from the liquid stream. A dedicated polymer feed system serves each point of use. A polymer feeder, is used to mix the polymer with service water and to transfer the resulting polymer mix.

Nutrient. Nutrient for the biological reaction consists of a 39% urea/di-ammonium phosphate (DAP) solution. The nutrient is stored in a 4,100-gallon FRP tank. Eight electric operated peristaltic pumps are used to pump the nutrient to the eight FBRs. The rate of nutrient addition to each FBR is in proportion to the feed flow to each FBR, and is operator-adjustable.

Electron Donor. Denatured ethanol (190-proof) is used as the electron donor and biological food source for the treatment system. The ethanol is stored in a 20,000-gallon double walled tank. Eight electric operated diaphragm metering pumps are used to pump the ethanol to the eight FBRs. The rate of ethanol addition to each FBR is in proportion to the feed flow to each FBR, and is operator-adjustable.

Ferric Chloride. Ferric chloride is used as a DAF coagulant and as a conditioning agent for the sludge prior to feeding the filter presses. It is stored in a 4,400-gallon FRP tank.

Hydrated Lime. The other conditioning chemical for the sludge is hydrated lime. The lime is stored on site in a 30-ton lime silo. The hydrated lime is fed to the conditioning tank in dry form using a screw conveyor.

Hydrogen Peroxide. Hydrogen peroxide is injected into the second-stage FBR effluent prior to the aeration vessel. The addition of hydrogen peroxide is paced based on on-line sulfide measurement to oxidize residual reduced sulfur.

UTILITIES – The utilities used by the system are as follows:

Compressed Air. Compressed air is necessary to operate equipment and instrumentation. Two rotary screw compressors provide this air. These 50-HP compressors can provide 240 ICFM at 110 psig each. All air generated by the compressors flows into a 660-gallon air receiver. Two filters remove remaining water droplets and oil from the air exiting the air receiver. Taking a portion of the total air and drying it with a desiccant type regenerative air dryer, provides instrument air.

Process Air. A dedicated blower provides the process air required for the aeration tank.

Service Water. Treated effluent is the main source of service water for the treatment plant. The service water is tapped on the pressure side of effluent pumps prior to the UV disinfection system. This provides a service water loop at approximately 30 psig. Stabilized lake water is used as makeup to the service water loop. Stabilized lake water is used for the eyewash stations and safety showers within the treatment plant. The safety showers and eye wash stations have scald and freeze protection.

Electric Power. All power to run the equipment for the FBR treatment facilities comes from a motor control center (MCC). The MCC is located in a climate-controlled enclosure in the treatment plant area.

CONTROL SYSTEM – The electrical control system contains a Siemens PCS7 system with Siemens PLC components. All I/O is contained in a cabinet with NEMA rated terminals for connection of field wiring. All automatic electrical devices (including motors) are controlled through the PLC, and displayed on screen. This includes approximately seventy (70) motors, approximately forty-five (45) 4-20 mA transmitters, and thirteen (13) 4-20 mA control valves. Manual controls are provided where required.

Figure 5. First-Stage Sand FBRs and Ethanol Storage.

PROJECT IMPLEMENTATION AND OPERATION

PROJECT SCHEDULE – The overall project took about two years to complete. The project schedule was as follows:

- Began process design Dec. 2002;
- Began laboratory pilot Jan. 2003;

- Began civil & mechanical design May 2003;
- Mobilized to the site June 2003;
- Completed installation Dec. 2003;
- Completed mechanical shakedown Jan. 2004;
- Inoculated system and began groundwater treatment Jan. 2004;
- Completed ramp-up of off-site well water and completely shut down Ion exchange July 2004;
- Added on-site well water and pond water Sept. 2004;
- Completed system acceptance test Nov. 2004.

PROJECT TEAM – The project team was made up of 4 companies - (1) Kerr-McGee Chemical, which was the client, (2) Shaw Environmental, which was responsible for the process design, pilot testing, mechanical design, reactor supply, and start-up assistance, (3) USFilter, which was responsible for instrumentation and controls design, aeration and DAF supply, and start-up assistance, and (4) Veolia Water, which was responsible for civil design, construction, balance of equipment supply, and plant operation.

PROGRESS TO DATE – By the end of 2004, the Kerr-McGee Chemical control strategy with biological treatment was completely in place and operational. The FBR system currently treats all the captured well water and has begun treatment of the stockpiled water in the holding pond. The biological system treats approximately 1,000 gallons per minute of combined well and holding pond water, and has consistently discharged less than 18 parts per billion of perchlorate. Nitrate and chlorate are also treated to below detection.

Effects on the Colorado River. Since implementing the control and treatment strategy in 1999, peak perchlorate concentrations along the Colorado River have dropped from a peak of about 10 ppb to about 3 ppb. The most dramatic declines in perchlorate concentrations along the Colorado River occurred after installing the FBR treatment system (see Figure 6). Since initiating groundwater flow through the FBRs, the three lowest concentrations ever measured at the Willow Beach, Arizona sampling point, located below the Hoover Dam on the Colorado River, were from February through April 2005, at 2.5, 2.3 and 2.3 ppb, respectively. Further declines are expected.

SYSTEM OPERATION – The treatment plant is manned 24 hours per day, 7 days per week. Routine operation primarily involves maintaining ethanol and nutrient dosing requirements via analysis of residual total organic carbon (TOC), ammonia-nitrogen and phosphate-phosphorus levels. Sulfide measurements and oxidation-reduction potential (ORP) are also routinely taken along the treatment train as an indicator of ethanol dosing and water quality.

Solids Management. Polymer and coagulant (i.e., ferric chloride) dosing to the DAFs is adjusted as needed to maintain a clear effluent water quality. On average, solids are conditioned every other day, and the presses are operated for 5 to 6 days per week. The plant is currently exploring the use of polymer alone as a conditioning agent to replace the ferric chloride and hydrated lime historically used.

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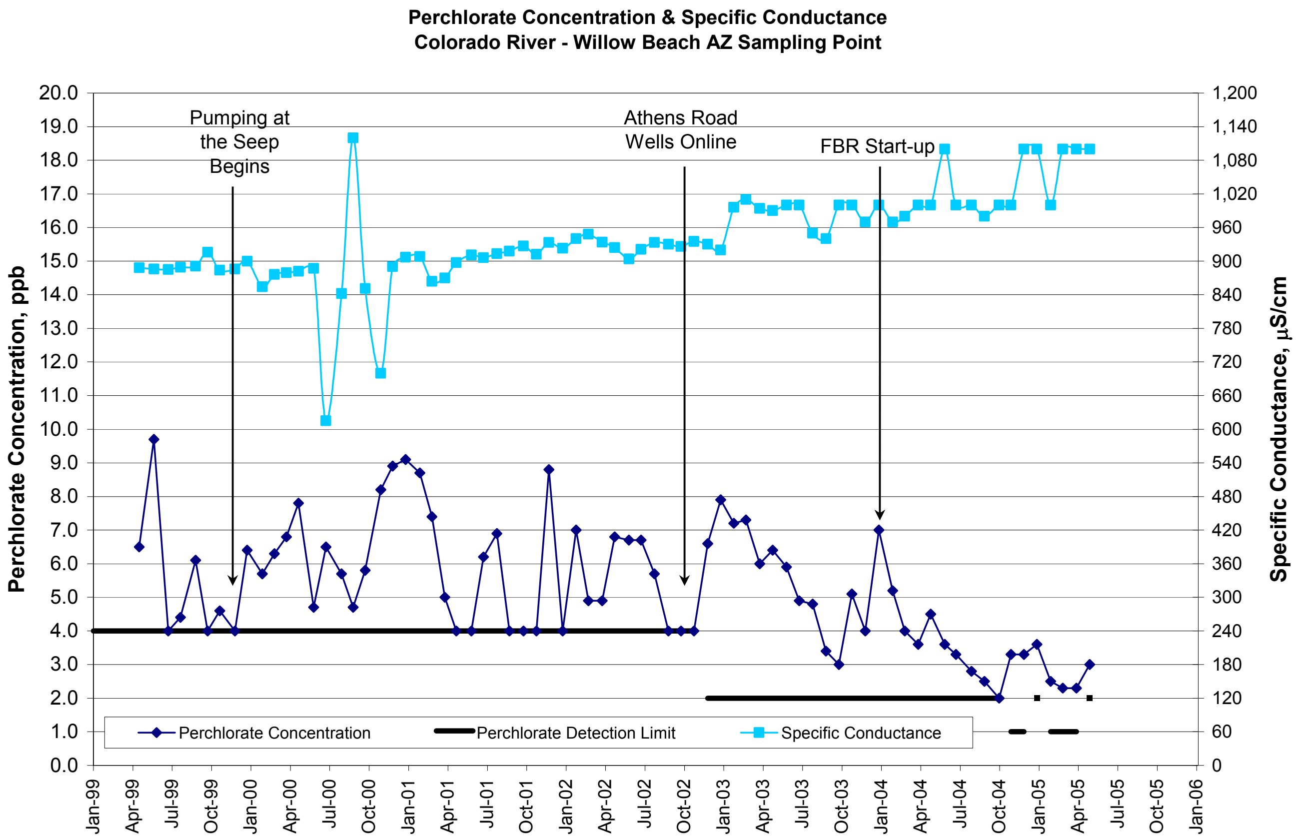
REFERENCES

Hatzinger, Environ. Sci. Technol. 39 (11) 239A-247A (2005)

Perchlorate Monitoring Results Henderson, Nevada to the Lower Colorado River December 2004 Report, U.S. Environmental Protection Agency, Region 9

Rikken, G.B., A.G.M. Kroon and C.G. van Ginkel, Appl. Microbiol. Biotechnol. 45 420-426 (1996)

Sutton, P. M. and M. R. Greene. “Perchlorate Treatment Utilizing GAC and Sand Based Biological Fluidized Bed Reactors,” Proceedings of the 1999 Water Environment Federation Conference, New Orleans, LA (1999



Notes: * Perchlorate concentration & Specific Conductance sampled on or about the 8th of each month.
* Willow Beach AZ sampling point is located along the east bank of the Colorado River approximately 11 miles downstream from Hoover Dam (Lake Mead).
* Approximate location: 35° 52' 26" N by 114° 39' 43" W

Figure 6. Perchlorate Concentration at Willow Beach AZ Sampling Point.