TREATMENT OF CONTAMINATED GROUNDWATER AT A SUPERFUND SITE

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SUMMARY

The purpose of this technical presentation is to share our practical experience related to a groundwater remediation project at a Superfund site. The project involved site evaluation, remedial action, feasibility study, technology selection, treatment plant design, and groundwater treatment plant operation. This paper briefly discusses the history of the site, in addition to the successful design and operation of the groundwater removal wells and the treatment plant to achieve the high degree of treatment necessary for direct discharge of the treated groundwater to the Missouri River. The hazardous waste treatment facility (Conservation Chemical Company – CCC) operated from 1960 to 1976 in Kansas City, Missouri. Many different types of hazardous and industrial wastes were treated and disposed of in six unlined basins at the facility. A total of 93,000 cubic yards of waste material were at the site. Leachate from the basins contaminated the groundwater beneath the site. The Missouri Department of Natural Resources (MDNR) ordered the site closure in 1977. During the time period 1977 to 1980 there were waste sludge stabilization activities. The remedial investigations were performed during the time period 1980 to 1985. In 1987 a Record of Decision and a Consent Decree were imposed to the offenders. In 1988 the site was capped and two pumping wells for extracting the groundwater and a treatment plant employing various physical-chemical and biological processes were constructed at the site to remove the inorganic and organic contaminants from the groundwater. In April 1990 the treatment plant started operations. The Consent Decree established operation of the pump and treat system for 20 years.

Key Words: Hazardous waste, leachate, pump & treat

INTRODUCTION

The CCC hazardous waste treatment facility operated from 1960 to 1976. Many types of hazardous and industrial wastes were treated and disposed of in six unlined basins at the facility. Leachate from the basins contaminated the groundwater underneath the site. Several remedial methods were evaluated for use at the site. The pumping and treatment of contaminated groundwater was chosen to control and treat the groundwater at the CCC site. This method can be used at sites where the contaminated zone of groundwater is confined or unconfined. A confined zone occurs when a natural or man-made barrier restricts the migration of groundwater form beneath the site. The unconfined site has no barrier to impede migration and thus relies more heavily on pumping. The CCC site is an example of pump and treat method applied to an unconfined site. Of significant importance is that the CCC site became the first remedial site to employ the pump and treat method in the Environmental Protection Agency’s (EPA) Region VII.

This paper discusses the site history and the steps taken to maintain excellence in water quality achievement throughout the past 12 years of operation. Two pumping wells for extracting the groundwater and a treatment plant employing various
physical-chemical and biological processes have removed contaminants from the groundwater to a level which allows direct discharge of the treated water to the Missouri River.

**SITE HISTORY**

The CCC site is adjacent to the Missouri River near the junction of the Blue River on the riverside of the levee in northeast Kansas City, Missouri. CCC was formed in July 1960 to store, treat and dispose of industrial and commercial wastes and sludges, cyanide compounds, organic solvents, spent oil, inorganic salts, pesticides, and miscellaneous organic compounds. Former treatment methods at CCC included neutralization, reduction, complexing, recovery, and incineration. The spent chemicals, sludges, and by-products of the treatment processes were stored in six unlined earthen basins. Liquid stream and sludges were discharged directly to the basins, while other materials were drummed prior to being placed in the basins.

In late 1975, CCC and MDNR discussed licensing of the site under the newly implemented Missouri Solid Waste Regulations. Site closure was ordered by MDNR in September 1976. Between 1977 and 1980, the top portion of the basin sludges were mixed with fly ash and pickle liquor. The stabilized sludge was then covered with a thin soil layer to form a plain surface over the basin areas. The EPA initiated a remedial investigation of the CCC site in March 1979. In November 1982, a civil action was initiated by EPA against CCC and those contributing wastes to the site. As a result of the remedial investigations, a Consent Decree, signed in April 1988 by the U.S. District Court, outlined the remedial action using the pump and treat method. The Front Street Remedial Action Corporation (FSRAC) was incorporated at the time by the contributing firms responsible for implementing the remedial action for the site. Construction contracts for the remedial work were in place by December 1988. Construction was completed in April 1990 for a new surface cap, site facilities, well systems, and the groundwater treatment plant. The capital cost for design and construction of the facilities outlined here was nearly $6.3 million.

**REMEDIAL INVESTIGATION**

The methodology used in this project followed the United States Environmental Protection Agency (USEPA) protocol for investigation and remedial action of contaminated sites according to CERCLA guidelines. The basic phases of these guidelines include:

- Phase I – Identification: Evaluation and preliminary site investigation
- Phase II – Priority List: Establish a priority location within the National Priority List (NPL)
- Phase III – Planning/Investigation: Perform a Remedial Investigation and Feasibility Study (RI/FS)
- Phase IV – Implementation: Design and implementation of the remedial action
- Phase V – Post-Closure: Audits and monitoring to ensure compliance

**PUMPING COMPONENT**

The pumping component of the pump and treat system must capture the contaminated groundwater before it migrates from beneath the site. Pump tests, hydrological analysis, and modeling are used to determine the required pump capacity. The capacity must be greater enough to develop a zone of influence extending beyond the contaminated area. The groundwater is pumped and treated until the contaminants are reduced to acceptable levels.

The groundwater monitoring well system including the two withdrawal wells is shown in Figure 1. Each withdrawal well is capable of pumping 150 gallons per minute (gpm). The artificial gradient or drawdown that each well produces extends beyond the site boundaries and overlaps that of the other well. Associated with each withdrawal well are two pairs of piezometer wells. The piezometers nearest each withdrawal well are located out of the range of steep hydraulic gradients directly adjacent to the withdrawal wells. The piezometers farthest from the withdrawal well are located near the site’s edge. The distance between the paired piezometers must be sufficient to measure the gradient between the wells. Figure 2 indicates the relative position of the withdrawal well and associated piezometer wells.

Instruments located near each piezometer pair pneumatically measures the differential between the groundwater surface in each well to 0.01 of an inch. Precision surveys and measurements, inclined manometers, and system checks help ensure system accuracy. The CCC site piezometer differentials must be maintained at a minimum 12-month average of 0.72 inch. Pumping at a combined flow of 150 to 180 gpm from the withdrawal wells, the average differential has been maintained between 1.1 inches and 2.4 inches over the past years in each of the four pairs of piezometer wells.
TREATMENT COMPONENT

The groundwater treatment plant has a hydraulic and contaminant reduction capacity to handle the combined, full capacity of the two withdrawal wells of 300 gpm. The actual design flows were established to produce the required 12-month average differential in the pair piezometers. Thus the average design flow of 160 gpm with a design peak flow of 210 gpm was determined in 1990. Changes in the river stage and/or existing geological conditions require a higher flow rate to maintain the required differentials.

The treatment plant is NPDES (National Pollution Discharge Elimination System) permitted by the State of Missouri to discharge the treated groundwater to the Missouri River. The permit requires analysis and compliance with a broad range of inorganic and organic constituents as well as biological toxicity. Thus the treatment processes were scrutinized in detail throughout the design process. A schematic flow diagram of the water and sludge handling processes are shown in Figures 3 and 4. Each unit process and its sequence in the treatment train were developed to meet specific treatment needs and complement other unit processes. The unit processes are: Equalization/mixing/air stripping, hydroxide precipitation (pH adjustment, rapid mix, flocculation, and clarification), pH adjustment, aerobic biological treatment, dual media filtration, granular activated carbon (GAC) adsorption, sulfide precipitation, final pH adjustment, and sludge thickening and dewatering. Descriptions for each treatment unit process are as follows:

**Equalization:** A 30,000-gallon equalization tank provides for the blending of the flow from the two withdrawal wells.
Diffused aeration is used for mixing and conversion of iron compounds from the ferrous to the ferric form for subsequent precipitation. At least 50% of the volatile organics are removed in this unit process. Treatment of the off-gas from the equalization basin is not required since its quality is within the quantities and regulatory standards.

**Hydroxide Precipitation:** The hydroxide precipitation (metals removal) system consists of several steps including pH adjustment with lime to form the metal hydroxide compounds, rapid mixing with polymer and slow mixing for floc formation, clarification for precipitated metals removal using a Lamella clarifier, and pH adjustment prior to the biological treatment system.

**Aerobic Biological Treatment:** The biological treatment system consists of two fixed-film packed towers with forced-draft aeration. Nutrients (such as anhydrous ammonia and phosphoric acid) and inoculum can be added to the biotowers to optimize biological growth. The system effectively reduces the soluble organics. The influent BOD concentration is fairly low and is difficult to use as an indication of removal effectiveness. The reduction of total phenols through the system has been the best indicator of treatment effectiveness.

**Dual Media Filtration:** The dual media filter removes solids carryover from the biotowers to protect the GAC adsorption columns, which follow. The filter can be continuously backwashed during its operation. Initial treatability studies indicated the small amount of solids generated in the biotowers could be handled by the filter without clarification prior to filtration.

**GAC Adsorption:** The carbon columns reduce the remaining concentration of organics to discharge permit levels. The units are operated in series, with either unit capable of operating as the lead column.

**Sulfide Precipitation:** The sulfide precipitation system uses pH adjustment and excess soluble sulfide to provide additional metals removal to concentrations lower than those achievable by hydroxide precipitation. Diatomaceous earth filtration is incorporated into the system to capture the precipitate and provide a clear effluent. The system was located near the end of the process stream to avoid the potential of elevated sulfides entering the biotowers.

**Final pH Adjustment:** The treated effluent is monitored prior to discharge to the Missouri River. Sulfuric acid and sodium hydroxide chemical feed systems are included in this final unit process to maintain the pH within limits of 6 to 10 in the discharge.

**Sludge Thickening and Dewatering:** The metals precipitates are gravity thickened in either the hydroxide sludge thickener or sulfide spent media thickener. Filter presses dewater the metals sludges, and the filter cake is transported off site for hazardous waste disposal.

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Figure 3: Groundwater Treatment Flow Diagram
TREATMENT PERFORMANCE

The groundwater treatment plant has been successful at removing organic and inorganic compounds from the groundwater since its start-up in 1990. Samples are currently taken on an annual basis from all monitoring wells at the site to track the concentrations of contaminants in the groundwater. Quarterly samples are also collected from the withdrawal wells, carbon column effluent, and plant effluent. The quarterly samples are analyzed for a broad spectrum of parameters including heavy metals, conventional pollutants (COD, and total organic halides), and priority pollutants (volatile organics, acid and base/neutral compounds, pesticides, and PCBs). In addition, the plant effluent is tested for an aquatic toxicity effect by performing an acute 48-hour static acute test on *Daphnia magna* and a 96-hour static acute test on *Pimephales promelas*. Weekly samples are collected of the plant influent, carbon column effluent, and plant effluent and analyzed for heavy metals to evaluate the performance of the metals removal equipment. The carbon column effluent and plant effluent data indicate that the majority of the metals removal occurs in the hydroxide metals precipitation system. The sulfide metals precipitation system does not consistently provide additional removal of metals from the groundwater, possibly due to the low concentrations in the influent to the sulfide system. The plant has maintained high removal efficiencies for heavy metals with effluent values typically below detection. Other pollutants monitored on a weekly basis include biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), arsenic, beryllium, cadmium, chromium, copper, lead, mercury, and cyanide (total and amenable). These compounds, if detected, are only present in very low concentrations in the effluent of the plant. Typical groundwater concentrations, expected treatment results, and actual 2001 treatment results are presented in Table 1 for heavy metals, cyanide, BOD, COD, and TSS.

### TABLE 1: Treatment Plant Performance Summary

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Groundwater Quality (mg/L) (Plant Influent)</th>
<th>Expected Treatment Performance (mg/L)</th>
<th>Monthly Average Discharge Limit (mg/L)</th>
<th>2001 Plant Effluent Quality (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1990(1)</td>
<td>2001(2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arsenic</td>
<td>0.090</td>
<td>&lt;0.040</td>
<td>&lt;0.010</td>
<td>0.090</td>
</tr>
<tr>
<td>Beryllium</td>
<td>&lt;0.002</td>
<td>&lt;0.005</td>
<td>&lt;0.002</td>
<td>0.020</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.030</td>
<td>&lt;0.005</td>
<td>&lt;0.004</td>
<td>0.050</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.200</td>
<td>&lt;0.010</td>
<td>0.010</td>
<td>0.200</td>
</tr>
<tr>
<td>Copper</td>
<td>0.260</td>
<td>&lt;0.005</td>
<td>&lt;0.007</td>
<td>0.050</td>
</tr>
<tr>
<td>Iron</td>
<td>375</td>
<td>16.5</td>
<td>0.020</td>
<td>No Limit</td>
</tr>
<tr>
<td>Lead</td>
<td>&lt;0.005</td>
<td>&lt;0.025</td>
<td>&lt;0.005</td>
<td>0.050</td>
</tr>
<tr>
<td>Mercury</td>
<td>&lt;0.0002</td>
<td>&lt;0.0002</td>
<td>&lt;0.0002</td>
<td>0.002</td>
</tr>
<tr>
<td>Nickel</td>
<td>0.245</td>
<td>0.045</td>
<td>0.080</td>
<td>2.38</td>
</tr>
<tr>
<td>Zinc</td>
<td>0.303</td>
<td>0.088</td>
<td>&lt;0.050</td>
<td>1.48</td>
</tr>
<tr>
<td>Amenable Cyanide</td>
<td>&lt;0.01</td>
<td>&lt;0.02</td>
<td>&lt;0.010</td>
<td>0.220</td>
</tr>
<tr>
<td>Total Cyanide</td>
<td>0.444</td>
<td>0.034</td>
<td>0.190</td>
<td>0.650</td>
</tr>
<tr>
<td>BOD</td>
<td>92</td>
<td>9.0</td>
<td>39</td>
<td>No Limit</td>
</tr>
<tr>
<td>COD</td>
<td>520</td>
<td>50</td>
<td>74</td>
<td>3.000</td>
</tr>
<tr>
<td>TSS</td>
<td>530</td>
<td>42</td>
<td>44</td>
<td>50</td>
</tr>
</tbody>
</table>

(1) 1990 groundwater values for all parameters except nickel, zinc, and total cyanide are equal to the expected plant influent and not the actual average of 1990 weekly sampling.

(2) 2001 groundwater and plant effluent values are equal to annual average of weekly sampling events for all parameters.
MONITORING AND CONTROL

Most equipment in the treatment facility is automatically monitored and PLC controlled through links to a PC based system at the treatment facility. This system makes operations and record keeping more efficient and economical. Fewer people are required to take readings and handle the data afterward. This automation allows the plant to operate 24-hours per day with only two employees who both work the same eight-hour shift. Most field equipment is linked to the computer, so plant operators can adjust some operational parameters without leaving the office. When monitored processes, including chemical, water, and pH levels needs attention, the alarm system alerts staff at the plant to take corrective action.

The plant reporting parameters (differentials, analytical quantities, and effluent volumes) recorded by the system are frequently verified with outside checks. The groundwater differentials recorded by this program are verified with frequent field measurements and periodic precision surveys to verify the piezometer well elevations. When sampling, proper techniques are followed and analytical work is periodically split between laboratories to verify results. Frequent instrument calibrations in the plant reduce chemical requirements and help maintain steady state conditions, while a preventive maintenance program minimizes down time and reduces the occurrence of upsets and the potential for permit violations.

EXPLORATION OF TREATMENT OPTIONS

Activities associated with operation of the FSRAC groundwater treatment plant extend beyond simply meeting the required NPDES discharge permit. FSRAC has explored several alternatives to minimize water and energy consumption and waste production. These alternatives achieve operating cost savings while continuing to produce high quality effluent minimizing water and soil pollution. Several alternative options explored include the following:

Wastewater Neutralization
Due to the low alkalinity of the wastewater, which caused low pH values in the biological tower, soda ash was added to the system to supplement the lime. As a result, smaller amount of metals precipitation sludge is generated, thereby reducing the cost and energy associated with dewatering and disposal of the sludge.

Sludge Treatability Study
In 1996 a sludge treatability study was conducted to determine the effectiveness of hydrogen peroxide in the treatment of the sludge generated at the FSRAC groundwater treatment plant. The goal of the study was to reduce the pesticide concentrations to levels that comply with the Universal Treatment Standards (UTS) for final disposal in a landfill and eliminate the need for treatment at the disposal facility. The results of the study did not result in a cost or chemical savings to treat the sludge on-site. The metals precipitate sludge continues to be analyzed and stabilized as needed at the disposal facility. At this time, the majority of the sludge loads do not require any further stabilization. The annual sludge generation is approximately 850,000 pound per year.

Waste Solids Water Content
The current sludge processing consists of dewatering with a plate and frame filter press. Sludge drying was evaluated in an effort to reduce disposal volumes and the cost associated with shipping and disposing of the dewatered sludge at a hazardous waste landfill. Sludge drying was capable of reducing the water content of the waste solids to nearly 98%. However, the capital, operational, and maintenance and energy costs associated with drying did not offset the transportation and disposal costs associated with disposing of the filter cake.

Reactivated Carbon Usage
Virgin activated carbon usage at the FSRAC plant has been replaced with reactivated carbon usage. The reactivated carbon can be supplied for significantly less cost than the virgin carbon. Carbon change-outs are scheduled following breakthrough from the lead column and use of reactivated carbon has not decreased the useful life of the columns. The carbon usage at the plant is approximately 240,000 pounds annually.

Dual Media Filtration
The dual media traveling bridge filter was experiencing significant downtime due to surface blinding of the media, requiring frequent replacement of the media. Improvements were suggested and initiated by plant operating personnel to increase backwash duration over each filter cell by adding a series of electronic control stops (the original design by the manufacturer only allowed the backwash bridge to move continuously). In addition, by connecting the plant non-potable water to a spray
wash header to surface scour the top media, backwashing was enhanced, lessen the headloss from the media blinding and increasing the filter run time significantly.

**Plant Effluent Water Reuse**
Plant effluent is used for all major water requirements for operation and maintenance of the treatment plant, including washdown of equipment, floor and vessels, as well as makeup water for chemical solutions. This reduces the requirement for potable water and also minimizes the discharge volume from the plant. Potable water is stored at the plant and used for the laboratory sink, workshop sink, safety showers, and eye washes. Bottled water is used for drinking purposes.

**Energy Efficient Air Diffusers**
Operation of the plant has been modified to include more efficient air diffusers in the equalization basin for mixing and aeration. The air diffusers replaced simple openings in the air headers. Diffusers increased the oxygen transfer efficiency.

**On-Line Data Management**
The treatment plant has been equipped with an on-line environmental management system that tracks the piezometer differentials and pumping rates. This on-line system allows the operators to maintain the required inward gradient with the minimum pumping rate, thereby minimizing effluent disposal to the Missouri River, and chemical and energy usage.

**Other Energy Saving Methods**
Although the plant operates 24 hours a day, 7 days a week, other non-treatment related energy uses were evaluated. Improvements and changes that have been made to reduce energy usage include leaving fewer lights on in the evening, maintaining a lower temperature in the plant during the winter months, and evaluating a more efficient heating system.

**COST SUMMARY**
The design and construction of the remedial project was divided into three major construction contracts: RA-1, RA-2, and RA-3.

**Contract RA-1 – Site Cleanup and Protective Cap**
Contract RA-1 covered the surface cleanup, surface preparation, and protective surface cap installation. It also provided for deposition of drill cuttings and other solid materials from Contract RA-2 and installation of the effluent outfall from Contract RA-3.

**Contract RA-2 – Withdrawal and Monitoring Well System**
Contract RA-2 covered the installation of the two groundwater withdrawal wells and the groundwater monitoring wells. It also provided for the installation of the paired piezometer wells, which measure the withdrawal wells effectiveness.

**Contract RA-3 – Groundwater Treatment Plant**
Contract RA-3 covered the construction of the groundwater treatment plant. It also provided for the installation of the groundwater influent piping from the withdrawal wells to the treatment plant, installation of the instrumentation for the two sets of paired piezometers, and the utility services required by the treatment plant with withdrawal well systems.

The cost of the design and construction of the remedial action are summarized as follows:

<table>
<thead>
<tr>
<th>Contract</th>
<th>Cost</th>
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</thead>
<tbody>
<tr>
<td>RA-1</td>
<td>$980,000</td>
</tr>
<tr>
<td>RA-2</td>
<td>$540,000</td>
</tr>
<tr>
<td>RA-3</td>
<td>$4,750,000</td>
</tr>
<tr>
<td>Total</td>
<td>$6,270,000</td>
</tr>
</tbody>
</table>

In addition to the design and construction cost of the remedial action plant, the operating and maintenance cost can be significant. The major operating costs for 1991 and 2000 are summarized as follows. The decrease in operation and maintenance cost is due to lower concentration of contaminants in the effluent and the implementation of the improvements presented in the previous section.

<table>
<thead>
<tr>
<th>Description</th>
<th>Year 1991</th>
<th>Year 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

7
<table>
<thead>
<tr>
<th>Item</th>
<th>Actual</th>
<th>Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Exchange</td>
<td>$383,000</td>
<td>45,400</td>
</tr>
<tr>
<td>Chemicals</td>
<td>$38,000</td>
<td>27,500</td>
</tr>
<tr>
<td>Sludge Disposal (hazardous waste)</td>
<td>$173,000</td>
<td>52,500</td>
</tr>
<tr>
<td>Equipment and Replacement Parts</td>
<td>$67,000</td>
<td>114,700</td>
</tr>
<tr>
<td>Utilities</td>
<td>$64,000</td>
<td>62,600</td>
</tr>
<tr>
<td>Professional and Laboratory Services</td>
<td>$509,000</td>
<td>339,500</td>
</tr>
<tr>
<td><strong>Total O&amp;M</strong></td>
<td><strong>$1,234,000</strong></td>
<td><strong>$642,200</strong></td>
</tr>
</tbody>
</table>

**SUMMARY**

The design of the FSRAC remedial action provides for treatment of contaminated groundwater and prevents further migration of the contamination through the subsurface, which yields a highly effective remediation process. Withdrawal wells are pumped at a rate to create a cone of depression keeping the contamination under the site from spreading to non-contaminated soils and water sources. Differentials are measured using a series of paired piezometers to ensure the necessary hydraulic gradient is maintained.

Physical-chemical and biological treatment processes are used in combination to effectively reduce organic compounds and heavy metals to below regulatory levels. Over the past twelve years of operation, FSRAC has maintained excellence in operation of its CCC site groundwater treatment plant. Specifically, the plant demonstrates significant achievement with its design, operation, and continued commitment to safety, quality assurance, and exploration of new technologies.

The daily operations of the plant are completed with only two full-time employees. Use of current technology allows the operators to track and control several plant operations from the office or their home via a modem. Use of this technology increases the operations and data documentation efficiency to allow the operators more time for preventive maintenance and good housekeeping activities.

Despite the quality performance of the plant, FSRAC continues to explore new technologies capable of reducing operating costs, energy use, and hazardous waste generation without compromising water quality standards.

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