CONTRACT TITLE: Treatment of Produced Oil and Gas Waters with Surfactant-Modified Zeolite

REPORT TYPE: Semi-Annual Progress

REPORT PERIOD: 1 May 2000 – 31 October 2000

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REPORT ISSUE DATE: October 2000

DOE AWARD NUMBER: DE-AC26-99BC15221

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CONTRACT PERIOD: 28 September 1999 to 29 September 2001

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Abstract

Whereas most water produced from onshore oil and gas operations is disposed via reinjection, some waters, such as those from offshore production platforms, coastal production, and some onshore wells, must be treated to remove organic constituents before the water is discharged. Current methods for reducing residual free phases and dissolved organic carbon are not always fully effective in meeting regulatory limits. In addition, cost, space requirements, and ease of use are important factors in any treatment system. Surfactant-modified zeolite (SMZ) has been used successfully to treat contaminated ground water for organic and inorganic constituents. This research will use laboratory batch and column studies to design a field system that will be used to treat produced waters to reduce dissolved and free-phase organic constituents. The system will be designed to operate simply and to have low operating costs. Methods for regeneration of the spent zeolite will also be tested, as will the treatment system at a field production site in the final project task.

Research over the past six months has focused on the method development, batch adsorption studies to demonstrate removal of target organic constituents, and the selection of a likely test site and characterization of produced waters from the site. Current contacts for selection, and ultimately, testing of example oil field waters include Phillips Petroleum Corp. (offshore location, Gulf of Mexico); MCA Petroleum Corporation in Flatonia, Texas; Amoco production in Farmington, New Mexico; and the New Mexico Bureau of Mines and Mineral Resources (mining operators for coal bed waters from the Farmington area). Water from Phillips Petroleum was received in August and analyzed at the University of Texas. These waters are being used in the laboratory to evaluate interactions between oil field waters and the SMZ. A site visit to MCA Petroleum operations was undertaken on October 12, 2000, and the analyses of samples taken are included in this report. MCA may not be chosen as a field site due to non-detected levels of volatile organic compounds in the sampled waters. Other field site contacts will be visited in November and December 2000.

Current funding to the subcontract with Los Alamos National Laboratory was not received from DOE until August 30, 2000, thus slowing progress in field test site identification. Improved contact with the State of Texas Railroad Commission will help to move this part of the project forward. New Mexico Tech has now acquired a full-time technician for regeneration testing.

Table of Contents

Abstract-----	1
Table of Contents-----	2
Introduction-----	3
Methods-----	3
Results/Discussion-----	8
Site Selection Process-----	14
Future Work-----	15

Introduction

Oil and gas produced waters are the largest waste-stream sources in the United States. These waters can contain many pollutants, including substantially high concentrations of volatile organic compounds (VOCs) benzene, toluene, ethylbenzene, and m-, o-, and p-xylenes (collectively known as BTEX) and a broad range of semivolatile organic compounds. While reinjection is the most commonly used method of wastewater management for onshore facilities, it is not always feasible because of geographic and cost considerations. In the case of offshore waters, discharge is the most practical and cost-effective means of treatment. In these situations it may be desirable, and often necessary from a regulatory viewpoint, to treat produced water before discharge. It also may be feasible to treat waters that slightly exceed regulatory limits for re-use in arid or drought-prone areas, rather than losing them to re-injection.

Surfactant-modified zeolites (SMZ) have been shown to be effective at removal of both organic and inorganic constituents in aqueous systems. The objectives of this study include the use of SMZ in laboratory batch and column studies to design a field-scale treatment system for the removal of BTEX and possibly other organic compounds from oil-field produced water. Methods for regeneration of spent SMZ will also be tested to determine the cost-effectiveness of the process. Pre- and post-treatment needs will also be studied. In the final phase of the research, a pilot plant system will be tested.

Methods

Table 1: Standard Solution Concentrations	
Desired Standard Solution Concentration µg/L	
	0
	9
	15
	30
	60
	120
	200
	500
	800
	1000
	1500

The complete method used for determination of BTEX concentrations in aqueous samples requires preparation of stock solutions and standard curve development. Samples are analyzed using an HP 5890 gas chromatograph. The aqueous solutions are prepared in 22 mL headspace vials (HP5182-0837). Standard curve samples are prepared and analyzed in triplicate to determine precision. An internal standard, α,α,α -trifluorotoluene (Restek), which is detected by the GC between benzene and toluene, is used to determine whether the instrumental apparatus is working properly and also to correct for any variation in

volatilization out of the headspace vials among these same vials. The ratio of the amount of BTEX detected to the amount of internal standard detected is used to generate the standard curve. This ratio should be constant among vials of the same concentration so

volatilization of individual compounds in the vials does not invalidate the analysis. Table 1 lists standard solution target concentrations.

Batch tests are performed to develop adsorption isotherms for the BTEX compounds onto surfactant-modified zeolite (SMZ). Samples from these batch tests are then analyzed with a headspace analyzer (HSA) and a gas chromatograph (GC).

A complete batch study involves saturation of the SMZ with water, introduction of BTEX compounds to the SMZ in an aqueous solution, mixing, centrifugation, sample extraction, and analysis. Batch studies are performed with triplicates for each concentration and for each type of vial: sample (including SMZ and BTEX) and blank (excluding SMZ but including BTEX). That is, for each initial BTEX concentration, there should be six vials. Three of these vials should not include SMZ and three should include 2.5 g of SMZ. This method allows statistical analyses to be performed on data.

- Saturation with Water

Saturation of the adsorbent with water is performed to avoid competition between water and BTEX compounds for adsorption sites when the compounds are initially introduced to the SMZ. The same 22 mL headspace vials that are used to prepare the standard curve solutions are used throughout the batch studies. All vials are first weighed with their crimp caps and septa loosely capping them. Once the vials are separated into adsorption samples and blanks, the vials that are to include SMZ are filled with 2.5 g of the adsorbent. Approximately 10 mL of Millipore water are then added to every vial and each vial is sealed. All of these vials are then placed in a tumbler in a 20°C constant temperature room and mixed for 24 hours.

- Injection of BTEX Compounds

After 24 hours of mixing, the vials are removed from the tumbler and uncrimped. Each vial is then completely filled with water to eliminate headspace in the system, loosely capped, and weighed. After measuring the water temperature, the density and mass are used to calculate the volume of water in each vial. Then, the correct volume of the proper stock solution is determined for each vial. This volume is injected with an appropriate Hamilton Gastight syringe near the bottom of each vial to generate a range of starting BTEX concentrations. The vial is immediately capped and sealed after injection. The stock solution is injected near the bottom of the vial so that the vial may be capped and sealed prior to the occurrence of substantial volatilization immediately after injection. After the vials are all properly sealed, they are again put in a tumbler in a constant 20°C room and mixed for 24 hours.

- Centrifugation

After all the vials have been mixed, a sample of only the aqueous portion of the solution must be analyzed. To do this, the vials must undergo centrifugation to separate the solid SMZ from the aqueous solution. A Beckman Model J2-21 centrifuge with a JA-20 rotor is used for this research. Eight samples are spun simultaneously at 4000 rpm for 30 minutes. The centrifuge has a temperature

control feature so the temperature is again kept constant at 20°C. All of the vials undergo centrifugation, even those with no SMZ.

- Sample Extraction

This part of the method is most susceptible to losses due to volatilization. After all of the vials have been centrifuged, some fraction of the supernatant must be extracted and injected into another headspace vial for analysis. Because the GC becomes saturated at concentrations greater than 1,500 µg/L, samples from all vials that contain solutions with initial concentrations greater than this value must be diluted so as to protect the GC. Samples from vials that do not contain concentrations greater than 1,500 µg/L do not have to be diluted and 5 mL of the supernatant can be directly injected into clean headspace vials, which are then immediately sealed.

For those samples that do not have to be diluted, a backpressure exists in the vial such that it is not possible to extract 5 mL without venting the vial in some manner. The vial can be pierced by another small syringe to create that venting. The syringe used to remove 5 mL of supernatant should be easily manageable and should not require a long amount of time or a great deal of effort. Either of these situations allows more time for volatilization losses to occur. Thus, in this research, a glass syringe with a glass barrel, rather than a Hamilton Gastight syringe, is used for this part of the procedure.

For samples that require dilution, proper volumes of Millipore dilution water are first pipetted into the headspace vials. Then, calculated volumes of supernatant are injected into this dilution water and the vials are immediately sealed. The volumes extracted for this dilution are usually small enough to forego the need for venting.

Once all of the vials have been sealed, an internal standard (α,α,α -trifluorotoluene) is injected into each vial in the same manner as stated above for the standard solutions. The vials are then placed on the headspace analyzer carousel and the amount of BTEX compounds remaining in solution after the batch test is determined.

Analytical Methods

Analysis of the standard solutions and the batch test samples and blanks involves a headspace analyzer, a gas chromatograph, and version 6.5 of the EZChrom Chromatography Data System (Scientific Software, Inc., San Ramon, CA (510) 244-6622). The headspace analyzer heats and mixes the solutions so that equilibrium between the gaseous and aqueous compounds is reached. Part of the headspace is then injected into the GC, which detects the compounds upon exit from the capillary column. EZChrom is used to integrate the area counts generated by the GC.

- A Tekmar 7000 Headspace analyzer is used to partition the BTEX compounds into the headspace and then to inject a sample of this headspace into the gas

chromatograph. During injection, both the sample loop and line temperatures are kept at 170°C.

- A Hewlett-Packard 5890 gas chromatograph fitted with a 30 m Restek capillary column (RTX-624; ID 0.53; DF 3.0) is used to measure the mass of BTEX compounds in the headspace of the samples.

It was found that the para-xylene and meta-xylene isomers are released at the same time of the ramping program. Further manipulation of the ramping program did not achieve separation of these compounds, so the combined mass of para-xylene and meta-xylene is measured. A representative chromatograph for the BTEX compounds is shown below in Figure 1, and Table 2 presents the times at which the peaks of the BTEX compounds are detected.

Figure 1: Typical Gas Chromatogram for Methanol, BTEX Compounds, and α,α,α -Trifluorotoluene

Table 2: Detection Times for BTEX Compounds	
Compound	Peak Detection Times (± 0.01)
	min
Benzene	2.84
α,α,α -Trifluorotoluene	3.40
Toluene	4.11
Ethylbenzene	5.90
p- & m-Xylenes	6.11
o-Xylene	6.84

Data Analysis

Data are collected with version 6.5 of the EZChrom Chromatography Data System. A standard curve is generated before the batch test vials are analyzed. In order to determine the true concentration of each BTEX compound in the batch test vials, corrections must be made to the nominal concentrations of the standard curve because of the differences between the densities and purities of each compound. This is most simply accomplished with a spreadsheet that contains the corrected concentrations. These corrected concentrations are then used in the linear regression to generate a more accurate standard curve. The linear regression is performed on the corrected standard concentrations and the ratio of the area of the BTEX compound to the area of the internal standard. If the residual sum of squares (R^2) is below 0.995, the standard curve is rerun. However, if the R^2 value is satisfactory, the standard curve is used to determine the concentration of BTEX in the batch test vials.

Once the concentrations of BTEX in the aqueous samples are determined, adsorption isotherms can be developed. Adsorption of these compounds to SMZ has been shown in the past to follow linear trends. Therefore, a linear adsorption model is also used in this research. The model used is:

$$q = K_d C_f$$

where:

q = mass of compound adsorbed/mass of adsorbent ($\mu\text{g/g}$)

K_d = distribution coefficient (L/g)

C_f = equilibrium concentration ($\mu\text{g/L}$)

The following equation is used to calculate q :

$$\frac{(C_i - C_f) * V}{M_{SMZ}} = q$$

where:

C_i = initial aqueous BTEX concentration, $\mu\text{g/L}$

V = volume of water in headspace vial during adsorption, L

M_{SMZ} = mass of SMZ, g

With these relationships, a plot of q vs. C_f can be developed and the slope of this linear function, which is the distribution coefficient, K_d , can be calculated. The distribution coefficient demonstrates the relative ease with which adsorption of a particular compound to SMZ takes place. As the value for K_d for a specific compound increases, the mass of that compound that is adsorbed also increases. Thus, large K_d values describe compounds that are readily adsorbed to SMZ.

Results and Discussion

Produced Water Characterization

Waters from two different oil fields were analyzed for various compounds, including BTEX. The first water was obtained from an offshore platform operated by Phillips Petroleum in the Gulf of Mexico. This sample was observed to be quite salty and had a distinct odor. In contrast, the second water sample, which was neither salty nor odorous, was obtained from onshore oil-producing fields operated by MCA Petroleum Corporation in Flaton, Texas. Results from the analyses are below.

- **Phillips Petroleum Offshore Sample**

The analysis conducted at the University of Texas at Austin for this sample consisted of identifying the amount of BTEX dissolved in the produced water. DHL Analytical laboratories in Round Rock, Texas, conducted further analyses of the concentrations of Total Petroleum Hydrocarbons (TPH), cations, and anions.

The BTEX analysis was conducted in the manner described above in the Methods section. Standard curves were initially developed prior to running the aqueous samples themselves. Rather than immediately run batch tests with these samples, an initial characterization of the water was conducted. The samples for this water were directly analyzed in the headspace sampler and GC. To reduce risk of saturating the GC detector, four of the six samples run were diluted prior to analysis. The standard curves were then used to quantify the BTEX concentrations in the produced water. The R^2 values for both the lower concentration region (0-120 $\mu\text{g/L}$) and the entire range analyzed (0-1500 $\mu\text{g/L}$) are presented in Table 3. Also included in this table are the average concentrations of BTEX found in the produced water.

The analyses completed by DHL Analytical all followed specified methods approved by the Texas Natural Resource Conservation Commission (TNRCC) or the U.S. Environmental Protection Agency (EPA). The TPH testing was

conducted via the TX1005 method whereas anion analysis was conducted under EPA SW9056 and cation analysis under EPA SW6020. Results from the ion analyses follow in Table 4. The TPH testing proved inconclusive for any hydrocarbons present below the detection limit of 5 mg/L. No petroleum hydrocarbons present at concentrations above this detection limit were detected.

The Phillips Petroleum water has the desired characteristics, but samples are not easily acquired because the samples must be obtained directly from the offshore platform in the Gulf of Mexico.

Table 3: Standard Curve R² Values and BTEX Concentrations in Phillips Petroleum Samples				
Compound	Standard Curve R ² Values		Phillips Petroleum Samples	
	Low Range (0-120 μ g/L)	Total Range (0-1500 μ g/L)	Average	Standard Deviation
			μ g/L	μ g/L
Benzene	0.9992	0.9996	835	43
Toluene	0.9977	0.9994	227	15
Ethylbenzene	0.9985	0.9993	19	1
p- & m-Xylenes	0.9985	0.9991	42	1
o-Xylene	0.9985	0.9993	48	1

Table 4: TPH and Ion Analyses for Phillips Petroleum Samples				
Analyses	Method	Result	Units	Reporting Limit
TPH	TX1005	None Detected	mg/L	5.0
Anions	SW9056			
Chloride		58700	mg/L	200
Nitrate-N		None Detected	mg/L	0.500
Sulfate		None Detected	mg/L	3.00
Metals	SW6020			
Calcium		1690000	μ g/L	5000
Magnesium		263000	μ g/L	1000
Potassium		151000	μ g/L	1000
Sodium		33200000	μ g/L	50000

- MCA Petroleum Corporation Onshore Samples**

Samples were taken both upstream and downstream of the detention ponds at the MCA Burselon oil field. The upstream samples were taken directly from an outfall from the tank used to separate oil and water. The downstream samples were taken from the discharge outfall from the last detention pond. This discharge was being applied directly to the land around it, in effect creating an artificial wetland.

DHL Analytical laboratories analyzed these samples for a number of parameters. The parameters that were tested for by DHL include the following: TPH, semivolatile organics, anions, aqueous ammonia, metals, and BTEX. The results from these analyses and the methods used by DHL are included in Table 5. The semivolatile organics analysis included 67 different chemicals. However, none of these compounds were detected above the detection limits so all of the 67 unique chemicals are not included in Table 5.

As seen in the Table 5, the MCA Petroleum water samples have very low concentrations of salt and undetectable amounts of BTEX both upstream and downstream of the detention ponds. Although the low salt concentrations may be a natural tendency for the water in the Flatonia, Texas area, the lack of BTEX compounds may be linked with the site's water discharge processes. As shown in Figure 2, the water from the separation tank is directly discharged into a pond via an open pipe. This allows substantial volatilization to occur both in the pipe and during the time when the water flow is exposed to the atmosphere. Thus, as these characteristics do not allow us to determine the efficacy of the proposed treatment process, this water will likely not be used in the study.

Figure 2: Produced Water Outfall on MCA Petroleum Corp. Oil Field

Table 5: Results from Analyses of MCA Petroleum Corp. Samples					
Sample Location	Analyses	Method	Result	Units	Reporting Limit
Upstream					
	TPH	TX1005			
	C ₆ -C ₁₀		None Detected	mg/L	4.72
	C ₁₀ -C ₂₈		7.45	mg/L	4.72
	Semivolatile Organics	SW8270C	None Detected	µg/L	Varies by compound
	Anions	SW9056			
	Chloride		20.9	mg/L	1
	Nitrate-N		None Detected	mg/L	0.500
	Sulfate		11.1	mg/L	3.00
	Aqueous Ammonia (as N)	M4500-NH3 F	0.716	mg/L	0.250
	Metals	SW6020			
	Calcium		2090	µg/L	100
	Magnesium		547	µg/L	100
	Potassium		1940	µg/L	100
	Sodium		211000	µg/L	5000
	Aqueous BTEX	SW8021B			
	Benzene		None Detected	µg/L	5.0
	Toluene		None Detected	µg/L	5.0
	Ethylbenzene		None Detected	µg/L	5.0
	Xylenes, Total		None Detected	µg/L	5.0
Downstream					
	TPH	TX1005			
	C ₆ -C ₁₀		None Detected	mg/L	5.81
	C ₁₀ -C ₂₈		None Detected	mg/L	5.81
	Semivolatile Organics	SW8270C	None Detected	µg/L	Varies by compound
	Anions	SW9056			
	Chloride		20.1	mg/L	1
	Nitrate-N		None Detected	mg/L	0.500
	Sulfate		10.1	mg/L	3.00
	Aqueous Ammonia (as N)	M4500-NH3 F	None Detected	mg/L	0.250
	Metals	SW6020			
	Calcium		2120	µg/L	100
	Magnesium		538	µg/L	100
	Potassium		1810	µg/L	100
	Sodium		189000	µg/L	5000
	Aqueous BTEX	SW8021B			
	Benzene		None Detected	µg/L	5.0
	Toluene		None Detected	µg/L	5.0
	Ethylbenzene		None Detected	µg/L	5.0
	Xylenes, Total		None Detected	µg/L	5.0

Batch Adsorption Studies

All adsorption studies conducted to date have been performed on artificially created aqueous solutions of BTEX. None of these solutions have contained salts, as a

representative salt concentration has not yet been determined. Once a site is finally selected and the water characterized, that sample's salt concentration would be replicated in any artificial solutions that are used in future batch studies. Data for Phillips petroleum and MCA will be used to bracket the correct ionic balance for future testing.

The studies reported in this paper were performed to ascertain whether values for distribution coefficients determined with the methods used in this research approximate values found in literature. In addition, the effects of co-solutes were also examined through comparisons of distribution coefficients found in single- and multi-solute systems. Thus far, the only single-solute system studied has included benzene. However, further studies involving the other BTEX compounds are in progress.

The isotherms developed for aqueous systems including only benzene and those including all of the BTEX compounds are presented in Figures 3 and 4, respectively. Table 6 summarizes both the distribution coefficients and R^2 values for the isotherms.

Figure 3: Linear Adsorption Isotherm for Aqueous Benzene on Surfactant-Modified Zeolite

Figure 4: Linear Adsorption Isotherm for Aqueous BTEX Compounds on Surfactant-Modified Zeolite **Table 6: Results from Batch Adsorption Studies with Synthesized BTEX Solutions**

Compound	Single-Solute (Benzene)			Multi-Solute (All BTEX)		
	R^2 Value	Distribution Coefficient	Maximum Initial Concentration	R^2 Value	Distribution Coefficient	Maximum Initial Concentration
		L/g	mg/L		L/g	mg/L
Benzene	0.9944	9.47E-03	75	0.9993	9.87E-03	10
Toluene	-	-	-	1.000	2.70E-02	10
Ethylbenzene	-	-	-	0.9999	6.92E-02	10
p- & m-Xylenes	-	-	-	1.000	7.49E-02	10
o-Xylene	-	-	-	0.9999	6.64E-02	10

As can be seen when Figures 3 and 4 are compared, the maximum values for q differ significantly among the solutes. The multi-solute study included two very high concentrations of all of the BTEX compounds (100 mg/L and 250 mg/L). It was found that a great deal of volatilization or other losses occurred for these two concentrations. Because the blank solutions (no SMZ) experienced approximately 60% losses, the extent to which decreases in the SMZ solutions could be attributed to adsorption was unknown. The presence of the SMZ changes the susceptibility of the BTEX compounds to volatilization so it could not be assumed that 60% losses occurred from volatilization in both solutions and the remaining losses in the SMZ solution occurred from adsorption. Thus, the results from the experiments with these two concentrations were not included in the final analysis.

The single-solute study was conducted with the following initial concentrations: 0, 5, 10, 100, 1000, 10000, 40000, 75000 $\mu\text{g/L}$ benzene. This study was conducted with triplicates for both blanks and samples. Thus, a total of 24 data points resulted from this study and all of these points were used to form the adsorption isotherm shown in Figure 3. The initial concentrations for the multi-solute study were: 0, 5, 10, 100, 1000, 10000, 100000, 250000 $\mu\text{g/L}$. As explained above, the last two concentrations were dropped from analysis because of large amounts of BTEX losses.

The resulting distribution coefficients for benzene were compared to values determined by co-PI Bowman. The studies conducted by Dr. Bowman and his research group involved the investigation of co-solute effects on distribution coefficients. However, the methods used for these studies differ from the methods used in the present work. Rather than using solutions of BTEX in methanol, Bowman et al. used aqueous saturated solutions of BTX. The distribution coefficients for benzene, toluene, and p-xylene with these methods were 6, 16, and 46 L/kg. Thus, the distribution coefficients obtained in the current research are somewhat higher than previously reported.

Through comparison of the distribution coefficients for benzene in both the single-solute and multi-solute tests, it can be seen that the presence of co-solutes does not have a substantial impact on the adsorption of benzene to SMZ. This finding supports the use of HDTMA-SMZ as an adsorbent because all of the BTEX compounds can simultaneously be removed from solution without decreasing the sorption efficiency of the SMZ. Single solute studies involving other BTEX compounds are currently in progress.

MCA Site Visit

Project personnel (NMT, LANL, and UT) met with Mr. Bill Dunk in Flatonia, Texas. Bill escorted us to three fresh-water producing well sites, selected as “typical” sites for MCA. The sites visited were also dependent upon access, due to poor road conditions from recent heavy rains. In order, the sites visited were: Arnim field, Well A10 (including discharge #860), a second Arnim location (private leaseholder), and Zumwalt field, well Homer Burleson #1 (including discharge #897). Each site has at least one producing well, a gun barrel oil-water separator, an oil storage tank or tanks, and a fresh-water discharge to a series of two small holding ponds. The first holding pond in each case had some quantity of oil adhering to the pond rim, and sometimes an oil sheen on the water. The second pond in series in each case appeared to be free of oil or sheens, and supported wildlife such as frogs or turtles and vegetation around the pond. Each secondary pond discharges to either a wetland/field area or small creek. Cattle and other livestock use this water in each case. The local landholders are dependent upon this water for watering livestock or for irrigated agriculture. Mr. Dunk noted that the water tends to have low conductivity (dissolved solids) and that the quality is somewhat dependent upon chemicals used in the producing well. In general, however, the water tends to be of better quality than the local shallow ground water. MCA is required by the state to test the discharge water regularly for a suite of parameters including ammonium, total dissolved solids, total petroleum hydrocarbons, and some metals. MCA in the future

will be converting many of these discharges to a single holding tank, replacing the ponds, with a direct discharge to the streams. This conversion is mostly for aesthetic, not treatment, purposes.

NMT, LANL, and UT took samples from primary discharge into the first pond (overflow from the gun barrel) and from the final discharge (overflow from the second, downstream pond) at the both the Arnim A-10 and Burleson #1 wells. Samples were taken for analysis of total major cations and anions, petroleum hydrocarbons, and BTEX. At the Burleson well only, a pressurized sample was taken for storage and future batch testing with SMZ at UT. Samples for pH and conductivity were taken for analysis at LANL.

The LANL samples indicated a low conductivity range of about 350-500 $\mu\text{S}/\text{cm}$ and a pH range around 8.4, within the range of “fresh” water. At the time of this report, organic parameter results indicated non-detection for BTEX compounds and a low detection for the C10-C28 range of total petroleum hydrocarbons. Based on these results, it will be desirable to examine other sites for a water with intermediate levels of conductivity/dissolved solids and a higher organic carbon content in the outflow. Previously obtained samples of offshore waters from Phillips petroleum will serve as an example of a high-TDS, high-organic-content water. Two advantages of the MCA site are the excellent cooperation of the operators and the ease of access to install a treatment system. The sites are within an approximately 1-hour drive of Austin, are generally flat and unobstructed, and have security gates. Conversion of the ponds to a tank storage/discharge system may have the effect of retaining more of the volatile and semivolatile hydrocarbons in the water, thus making the SMZ treatment system an important addition to the discharge. Discussions will continue with MCA to identify other potential sites. Further contacts are being sought for an intermediate TDS site.

Future Work

Evaluation of other sites for produced water is presently being conducted. Water with high salt concentrations and substantial BTEX contamination are preferred so that field studies can be conducted at the site in the final phase of this study. In addition, the site must be sufficiently accessible to researchers to allow for timely water collection and minimal storage time. Once a site is selected for this study, further batch tests will be run with this water and adsorption isotherms will be generated. These tests will examine the effects of ionic strength on adsorption of the BTEX compounds to SMZ. In addition co-solute effects will be investigated further.

Column studies will be initiated shortly. The equipment for this phase of the project has been procured and researchers are currently establishing the procedures to be used for these tests. New students have been brought into the project at New Mexico Tech. and at UT Austin. Because of this, the different phases of the project will begin to be conducted concurrently. As such, the project should progress more quickly.