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Identification of Environmental RD&D Needs

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Final Report

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EXECUTIVE SUMMARY

The objective of this project was to identify new environmental research development and demonstration needs that have the potential to improve the performance of the oil and gas exploration, drilling and production technologies for maximum recovery of domestic petroleum resources under optimal environmental and economic conditions. To achieve this objective several areas of work were addressed. The first task was to compile as much related data as possible. This was achieved by literature searches of several petroleum related data bases. After acquiring sufficient background on environmental and economical areas that should be expanded, experts who are knowledgeable in these areas were contacted to further define specific issues. Also, the identified subjects were submitted to an in-house panel at NIPER to assure that the final environmental research demonstration and development needs selected to be expanded were unbiased and worthy of additional work.

Specific subjects were expanded and prioritized in the following order: (1) Mechanical Integrity Testing of Injection Wells by Oxygen-Activation Log, which would determine if fluid flow is occurring in the well annulus, (2) An Alternative Bioassay Test to assure the toxicity levels of offshore drilling fluids, (3) An Environmentally Safe Drilling Fluid to be used in the event of stuck pipe or similar circumstances, (4) Bioremediation of Waste Pits Using the latest in biotechnology to clean/remediate oilfield waste pits, (5) More Efficient Means of Technology Transfer to ensure that the latest environmental techniques and information being developed are readily available, (6) A Comprehensive Waste Management Protocol to evaluate wastes produced and determine the best techniques for reduction and/or disposal, and (7) A Pollution Prioritization Protocol for Abandoned Wells which would aid in defining the economic and environmental impact of abandoned wells.

IDENTIFICATION OF ENVIRONMENTAL RD&D NEEDS

By Michael E. Crocker, Michael P. Madden, and Roy Porter

ABSTRACT

The objective of this project was to identify needs for environmental research development and demonstration projects that have the potential to improve the performance of oil and gas exploration, drilling, and production technologies for maximum recovery of domestic petroleum resources under optimal environmental and economic conditions. To achieve this objective several areas of work were addressed. The first task was to compile as much related data as possible. This was achieved by literature searches of a number of petroleum-related data bases. After acquiring sufficient background on environmental and economical areas that should be expanded, experts who are knowledgeable in these areas were contacted to further define specific issues. More than 33 identified areas were submitted to an in-house panel at NIPER to assure that the final environmental research demonstration and development needs that were selected to be expanded were unbiased and worthy of additional work. Specific subjects that were expanded include: (1) The Mechanical Integrity Testing of Injection Wells by Oxygen-Activation Log, (2) A More Rapid or Alternative Bioassay Test, (3) An Environmentally Safe Drilling Fluid Additive, (4) Bioremediation of Waste Pits, (5) A More Efficient Technology Transfer, (6) A Comprehensive Work Management Protocol, and (7) A Pollution Potential Prioritization Protocol For Abandoned Wells.

I. DEVELOPMENT OF ENVIRONMENTAL RD&D NEEDS

INTRODUCTION

The Safe Drinking Water Act (SWDA) of 1974 and the amendments of 1980 attempted to balance the need to protect underground sources of drinking water (USDW) supplies while not interfering with oil and gas production or unnecessarily disrupting existing state underground injection control (UIC) programs. As part of the 1980 amendments to the Resource Conservation and Recovery Act (RCRA), the Environmental Protection Agency (EPA) was required to

present to Congress a report on the potential damage to United States drinking water supplies from current petroleum industry practices.¹ The Department of Energy (DOE) assisted the EPA in the development of this Report to Congress by providing various resources to improve the technical accuracy of the report as well as detailed comments on interim reports for the EPA. Because of the balanced perspective of the resulting Report to Congress, it was decided that drilling muds and produced fluids would not be classified as hazardous wastes. However, the report did identify some areas of concern that may constitute a "significant national problem" that may result in changes in the UIC regulations.

An integral part of removing impediments to domestic oil and gas exploration, development, and production is to ensure that any new regulatory requirements to protect the environment are reasonable and that associated costs and benefits have been carefully considered. DOE efforts related to the definition of an expanded petroleum research program have indicated that environmental research is needed to form a scientific basis for regulation and for the design of mitigation strategies. Several ongoing EPA initiatives related to oil and gas operations underscore this need. The following are examples:

- to design and implement a program specific to crude oil and natural gas wastes under Subtitle D of RCRA;
- to revise federal programs for controlling discharges from onshore and offshore oil and gas operations under the Clean Water Act and underground injection from oil and gas wells under the Safe Drinking Water Act; and
- to develop a research, development, and demonstration (RD&D) plan based on the findings of the December 1987 Report to Congress.

The EPA Office of Drinking Water has recently begun a mid-course correction (MCC) strategy that will address the areas of concern identified in the report to Congress. Again the DOE will be involved in a supporting role to provide a balanced perspective of petroleum production practices and to assist in accurate evaluations of the problems and trade-offs.

An important trade-off to assuring protection of USDW is the economic production of the United States petroleum resource. Petroleum producers,

especially marginal stripper well producers, have experienced difficult economic times in the past few years. Excess production capacity outside of the United States has depressed oil prices, and many domestic wells are being shut-in prematurely. Current regulations require permanent plugging of wells that are abandoned to protect USDW, but this practice eliminates the potential application of advanced petroleum production technology available in the future. These well abandonments cause a reduction of the country's petroleum reserves. As sources outside the United States supply higher percentages of the total oil consumed, additional policy issues, such as national security and the balance-of-trade deficit, become important considerations.

This report delineates recent developments in environmental RD&D needs that have the potential to improve the performance of oil and gas exploration, drilling and production technologies for maximum recovery of domestic petroleum resources under optimal environmental and economic conditions. This was achieved by approaching the problem systematically as can be seen in figure 2. The first objective was to obtain as much background information as possible by means of literature searches of related petroleum data bases. After sufficient background information was obtained on specific environmental areas, experts who are knowledgeable in those areas were contacted to further define a specific issue. These selected subject areas and others found in the data base searches were submitted to an in-house panel at NIPER to assure that the final environmental research demonstration and development needs to be included in the final report were unbiased and worthy of additional expansion as seen in figure 2.

Background Information

The practice of injecting fluids into oil-producing reservoirs to increase production is nearly as old as the petroleum industry. The earliest water-floods were used simply to meet needs to dispose of unwanted produced brines. However, increases in production because of the brine disposal resulted in the evolution of current enhanced oil recovery (EOR) technologies.

Early injection practices gave little or no attention to the environment. Other than those areas which were visible, such as brine damage to croplands, very little attention was given to possible or actual damage to subsurface environments for many years. Fortunately, improvements in

drilling, completion, and production practices have reduced risks to drinking water contamination through improved tools and better tubular goods, cementing, packers, etc. Although the purpose of these improved methods was to reduce costs or increase production, a side benefit has been more secure wells with less potential for contamination of upper water zones.

Because of environmental concerns, Congress passed legislation (SDWA of 1975) giving the Environmental Protection Agency the responsibility to protect the Nation's underground drinking water resource from contamination. The SDWA specifically lists petroleum injection wells (Class II wells) as potential sources of such contamination. Since the enactment of SDWA, significant progress has been made to protect USDW. The 1987 Report to Congress generally concluded that current federal regulations and current technologies are adequate to protect USDW with a few exceptions. Most cases of damage to the environment documented in the report occurred before regulations were in effect or involved violations of current regulations. The trend in industry practice is toward more desirable technologies and practices such as closed systems.

The Report to Congress identified concerns and potential improvements in oil and gas production practices, some of which are listed below:

- technical improvement in future technologies and processes such as thermal treatment for drilling fluids;
- conservation, recycle, reuse, and other waste minimization techniques;
- application of wet air oxidation and other proven technologies to the oil and gas operation;
- special concern about the environmental performance of waste management on the North Slope. Current data are limited and preliminary on the environmental impact of discharging reserve pit supernatants onto tundra and applications to roads as a dust suppressant;
- the need to separate low volume, high-toxicity wastes, such as unused pipe dope and motor oil, from large volume wastes; and
- development of innovative approaches to waste control, such as substitution of less toxic compounds for regeneration of drilling muds.

Regulatory changes have become confusing and expensive. The rapid increase in the number of regulations imposed on producers is shown in figure 1. Required well tests are sometimes redundant and often expensive. The paper-work burden on small operators is one cause for abandonment of marginal wells.

The federal effort to protect underground drinking water resources could and should be directed towards finding better ways to assure the integrity of Class II injection wells and behind-the-pipe migration of fluids. However, priorities must be established to assure that available research dollars provide maximum protection to the environment with minimum adverse economic impact to operators. Before passage of the SDWA in 1974, regulation of subsurface injection wells was the sole responsibility of individual states. Oil-producing states developed their own regulations to deal with the problems associated with injection of produced brines. Effective as these laws might have been in protecting the environment, their main objective was to protect and improve oil production. The many thousands of unplugged abandoned wells in this country are evidence of these earlier practices. The EPA considers that these unplugged wells pose a significant environmental impact. Although the number of documented cases of oil field pollution of freshwater aquifers by injection of produced fluids are few, problems do exist.²

FIGURE 1. - The increasing regulatory burden on the petroleum industry through 1981 (source: DOE/EIA-0329).

The greatest protection of USDW comes from factors that cause oil and gas to accumulate. By definition, oil can only be found in productive amounts when a confining layer or trap exists to keep mobile fluids in one place. This confinement does not allow pollution of fresh groundwater above the oil unless the seal is broken by the drilling of an oil well. However, a properly completed production well has little chance to cause contamination because fluids are being withdrawn from the confined zone. Introduction of deleterious materials to a freshwater aquifer can occur if produced brines are retained at the surface in such a manner that percolation into a near surface USDW can occur.

With the advent of injection practices for enhanced oil recovery and disposal, the probability of pollution has been increased because fluids are injected under pressure into confined zones leading to the possibility of fluid migration back up the outside of the casing of an injection well or through a leak. The EPA's UIC program was designed to allow for underground injection to continue, but with protection of USDW as the main concern.

Since December of 1974, the EPA has been responsible for protecting the Nation's USDW. The new federal regulations concerning UIC were met with opposition from the oil industry because of fears that new regulations and subsequent "red tape" would make marginal fields too costly to operate. After considerable debate, the SDWA was amended in December of 1980 (section 1425) to allow states more flexibility in gaining EPA approval for Class II well injection programs if they were found to effectively protect USDW. As of November 1987, 20 state programs have been accepted by the EPA under this amendment. Once a state's program has been accepted by the EPA, the state then has the authority to administer its approved UIC program. This return of authority to state governments is known as primacy. For other states that do not meet EPA requirements or have not applied for primacy, federal programs have been implemented.

EPA's UIC regulatory program is contained in 40 Code of Federal Regulations (CFR) Parts 124 and 144-146. These rules are joint agreements resulting from a process of public hearings, amendments, litigation, and close work among EPA, local governments, the oil industry, and environmental action groups. Some provisions of these regulations are summarized as follows:

- 40 CFR Part 124 contains the procedures for permit application and issuance for states that have not applied for primacy and have EPA administer UIC programs.
- 40 CFR Part 144 lists the overall framework of Regulatory authority for the UIC programs.
- 40 CFR Part 145 contains the requirements for approval of state UIC programs by the EPA.
- 40 CFR Part 146 contains technical standards that the EPA uses in operation of the UIC program. This section divides subsurface injection wells into five classes so as to administer different regulations under the UIC. Wells involved with injection of fluids recovered from the primary production of oil and gas, for enhanced recovery of oil and gas, or for storage of liquid hydrocarbons are considered to be Class II. Areas of interest for Class II wells are criteria for exempted aquifers, area of review (AOR), corrective action, mechanical integrity testing (MIT), and plugging and abandoning.

All EPA-approved, state-implemented UIC programs must provide equal and sufficient protection of USDW. The state programs vary because of the incorporation of state specific needs and differences, but these variations should have no effect on the minimum protection of USDW. However, differences in state UIC programs and implementation procedures will cause inconsistencies in USDW protection. The MCC strategy is designed to deal with this problem.

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Special thanks also to the in-house panel for providing assistance in selection of the final topic areas.

Several contributors who are experts in their field were instrumental in providing additional insight to the project, and they include:

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J. Thornhill	U.S. Environmental Protection Agency
J. Gall	Phillips Petroleum Company
E. C. Donaldson	University of Oklahoma
C. Goodner	Disposal Systems, Inc.
P. S. Jones	Chevron Oilfield Research
D. Eno	Exxon, USA
D. Warner	University of Missouri
J. Lynn	Underground Injection Practices Council
J. H. Robins	Amoco Corporation
W. T. Dowd	Interstate Oil Compact Commission
H. Yates	Exxon, USA
B. Freeman	Shell Oil Company
J. Simmons	Interstate Oil Compact Commission
W. Stewart	Phillips Petroleum Company

SEARCH TECHNIQUES

Several data bases were searched to obtain abstracts found in appendix A. A listing of data bases searched is shown in table 1.

TABLE 1. - Data bases searched

1. NTIS
2. Compendex
3. Geoarchive
4. Energyline
5. GEOREF
6. DOE Energy
7. API
8. Petroleum Abstracts
9. Enhanced Recovery Week
10. Chemical Abstracts

Keywords used for each selected data base are unique; however, a general listing of specific subjects used in the data base literature searches is shown in table 2.

TABLE 2. - Typical keywords used for database searches

<u>WELL</u> -	<u>OIL PRODUCTION OR GAS PRODUCTION AND WASTE</u> -
PLUG	OIL (W) PRODUCTION
POLLUTION	GAS (W) PRODUCTION
CORRECTIVE (W) ACTION	OIL OR GAS PRODUCTION AND WASTE
SHUT AND ABANDONMENT AND POLLUTION CONTROL	AND RECYCLE OR RECLAIM
STRUCTURAL INTEGRITY	<u>TOXIC OR TOXIC EFFECT OR TOXIC CHEMICAL AND DRILLING FLUID OR DRILLING MUD OR WORKOVER</u> -
MECHANICAL INTEGRITY	
INJECTION	TOXIC (W) EFFECT
CONSTRUCTION	TOXIC (W) CHEMICAL
SUBSURFACE TRANSPORT	DRILLING (W) FLUID
<u>DRILLING</u> -	<u>GROUNDWATER</u> -
WELL	CONTAMINATION
CONSTRUCTION	TOXIC (W) EFFECT
WELL (W) CONSTRUCTION	TOXIC (W) CHEMICAL
EQUIPMENT	
WASTE DISPOSAL	<u>AIR</u> -
PRACTICE	TOXIC (W) EMISSIONS
STORAGE	NO _x , SO _x , PARTICULATES
<u>OIL</u> -	<u>SOLID WASTE DISPOSAL</u> -
(W) WELL	DRILLING
WASTE	MUD/CUTTING
DISPOSAL	TOXICITY
(W) WELL AND DISPOSAL	<u>LAND USE</u> -
<u>ENVIRONMENT</u> -	SITE RESTORATION
(W) CONTROL	LAND FARMING
POLLUTION	TOXICITY
POLLUTION (W) CONTROL	
ENHANCED (W) OIL (W) RECOVERY	
CONTROL OR POLLUTION CONTROL AND EOR	

The Petroleum Abstracts data base indexes all forms of technical literature and patents pertaining to all upstream (petroleum exploration, development, and production) aspects of petroleum since 1960.³ However, in this search all data bases were reviewed only for 1984-1989. Petroleum Abstracts has more than 375,000 items in its files. Some 18,000 new citations are added to the data base each year and include:

- Geology
- Geochemistry
- Geophysics
- Drilling
- Well Logging
- Well Completion and Servicing
- Production of Oil and Gas
- Reservoir Engineering and Recovery Methods
- Pipelining, Shipping and Storage
- Ecology and Pollution
- Alternate Fuels and Energy Sources
- Supplemental Technology
- Mineral Commodities

A typical subject search in Petroleum Abstracts resulted in a listing of citations, as shown in table 3.³

TABLE 3. - Typical Petroleum Abstracts subject search

Subject	Citations
SS1: Drilling fluid (7694)	7,694
SS2: Drilling waste disposal (81) or (drilling fluid and waste disposal (282)	363
SS3: 1 or 2	7,742
SS4: 1 and 2	352
SS5: 3 and Bioassay/it (138)	37
SS6: 3 and marine ecology (2814)	182
SS7: 1 and fish (1501)	42
SS8: 2 and toxic effect (2985)	282
SS9: 2 and food/it (172)	1

Many the of citations required screening to reduce the total to a manageable and relevant data source, as shown in Appendix A.

SCREENING TECHNIQUES

Several techniques were used to compile and assemble the acquired material into the most favorable format for further availability and use. There were a number of steps where interaction occurred in the screening/selection process. Initially, this involved the literature search. Several data bases were researched, and large volumes of data were reduced to those which had the most merit. Several related Underground Injection Practices Council and Society of Petroleum Engineer meetings were attended which further aided in developing and formulating specific topics.

After sufficient material had been acquired and subject areas determined, they were assembled into a more usable format that would permit an overview as an aid in determining topics to be expanded.

Environmental RD&D needs presented in table 4 are separated into major topic areas that include:

1. Toxicity test of drilling fluids,
2. Drilling fluids,
3. In situ treatment of wastes/soils,
4. Disposal pit pollution,
5. Abandoned wells,
6. Oilfield brine treatment,
7. Mechanical integrity,
8. Injection wells,
9. Toxic materials,
10. Offshore waste disposal,
11. Hydrocarbon contamination,
12. Biodegradation, and
13. Waste management.

At this point, sufficient material and knowledge were available to begin the actual screening phase. This was accomplished in several ways. In one instance, an in-house panel (see appendix B) was assembled to review the aforementioned material, discuss the project goals, and rank the selected topics. This listing and ranking is found in appendix B.

TABLE 4. - Relationship of selected environmental needs to potential research

Topic	Ref. ¹	Regulatory/ programmatic relationship	Potential research	Research In progress	Tech. transfer
1. Toxicity test for drilling fluids					
a. free oil content of drilling muds	1	EN	X	X	
	47	EN	X	X	
	62	EN	X	X	
b. new test for LC50	3	EC/EN			
	4	EC/EN	X	X	
c. low toxicity drilling fluids/lubricants	1	EN			
	29	EN	X	X	
d. other	2	EN			X
	53	EN	X		X
	55	EN	X	X	
2. Drilling fluids					
a. free solids removal	1	EC	X		
b. heavy metals/organics removal	6	EC/EN	X		X
	33	EN	X	X	
	34	EN	X	X	
	35	EN	X	X	
	59	EN	X	X	
	79	EN	X	X	
c. disposal/landfarming	7	EN	X	X	X
	8	EN		X	X
	9	EN/R		X	X
	10	EN		X	X
	11	EN		X	X
	31	EN	X	X	
	64	EN/EC/R			X
	71	EN/EC	X	X	
	76	EN	X	X	
d. regulatory	28	EN/R		X	X
	52	R		X	X
	61	EN/R			X
	65	EN		X	X
e. other	38	EN		X	X
	39	EN		X	X
	40	EC/EN		X	X
	41	EN		X	X
	51	EN		X	X
	53	EN		X	X
	54	EN		X	X
	83	EN	X	X	
3. In situ treatment of wastes/ soils					
	12	EN	X	X	
4. Disposal pit pollution					
a. preventing leakage	13	EN		X	X
	46	EN		X	X
	49	EN		X	X
b. elimination of waste pits	14	EN	X	X	

TABLE 4. - Relationship of selected environmental needs to potential research – Continued

Topic	Ref. ¹	Regulatory/ programmatic relationship	Potential research	Research In progress	Tech. transfer
5. Abandoned wells					
a. plugging using gel	16	EN	X		
b. groundwater pollution	17	EN	X		
c. transport factors	17	EN	X		
d. drilling mud as plugging agent	18	EN	X	X	
6. Oilfield brine treatment	19	EN	X	X	
7. Mechanical Integrity of of Injection wells					
a. compliance	75	R			X
b. integrity	21	R			X
	32	R		X	X
c. repair	22	EC	X	X	
	25	EC	X	X	
d. tests	20	R	X	X	X
e. oxygen-activation log	103	EN	X	X	
8. Injection wells					
a. research	23	EN/R.	X		X
	24	EN/R	X		X
b. compliance	43	EN/R	X		X
c. effects	54	EN			X
9. Toxic materials					
a. fate	1	EN	X		
	5	EN	X		
	45	EN	X	X	
b. disposal	67	EN	X		
10. Offshore waste disposal					
a. effects	26	EN	X	X	
b. fate	53	EN	X	x	
	58	EN	X	X	
11. Hydrocarbon contamination					
a. removal	15	EN	X	X	
	27	EN	X		X
	42	EN	X	X	
	48	EN		X	X
	50	EN	X	X	
	60	EN	X	X	
b. fate	53	EN	X	X	X
	51	EN		X	X

TABLE 4. - Relationship of selected environmental needs to potential research – Continued

Topic	Ref. ¹	Regulatory/ programmatic relationship	Potential research	Research in progress	Tech. transfer
12. Biodegradation					
a. bioreclamation	44	EN	X		
	63	EN	X	X	
	77	EN	X		X
	78	EN	X		X
	81	EN	X	X	
	84	EN	X	X	
	85,94	EN	X		X
13. Waste Management					
a. implementation	68	EN/R	X	X	X
	74,99	EN/R	X	X	X

EN = environmental

EC = economical

R = regulatory.

¹References in Appendix A.

Concurrently, the selected subject areas were discussed with experts in industry, academia, etc. in order to provide additional input to the project and present information that would prevent the final report from being biased. This step was accomplished by means of telephone, personal, and letter contacts. An example of a typical letter used to contact others knowledgeable in specific areas is found in appendix C. In each case, a section of the letter was changed to include the area of interest for that specific contact. Also, a total listing of experts contacted is shown in appendix D. Response from these various modes of contact proved to be varied. Some of the contacts were very helpful in providing exact information to aid in completion of the final report. Other contacts only offered confirmation and agreement regarding preselected topics.

The selected topics were then expanded into the format previously noted and prioritized. A flow chart depicting the entire selection process is shown in figure 2.

FIGURE 2. - Process for developing environmental RD&D needs.

REFERENCES

1. Report to Congress: Management of Wastes From the Exploration, Development and Production of Crude Oil, Natural Gas and Geothermal Energy. EPA/530-SW-88-003, Dec. 1987.
2. Warner, D. C. Abandoned Oil and Gas wells and Their Environmental Implications. Pres. at the UIPC Summer Meeting, Portland, OR, July 31-Aug. 3, 1988.
3. Wares, C. S. Information Research Methods: Drilling Fluids and Drilling Work Disposal. Pres. at Environmental and Groundwater Institute, Univ. of Oklahoma, May 28, 1987, pp. 38-58.

II. SELECTED ENVIRONMENTAL RD&D NEEDS

INTRODUCTION

The following section contains both the brief summaries and the expanded concepts found to be related to environmental RD&D needs.

As noted, the objective of this project was to develop concepts based upon literature surveys and contacts with others which could be considered for future research and development. The expanded concepts are those selected for this purpose. Each subject area was expanded according to the following outline, if possible:

1. area of concern (or concept);
 - a. what is the concept?
 - b. what economic and environmental impact the problems?
 - c. solutions?
2. brief summary of any current related state-of-the-art;
3. identification of related areas for which technology is currently being addressed by industry;
4. areas not well addressed and for which DOE might play a role
 - a. why should DOE play a role.
5. economics
6. related references.

Some aspects of this section were taken directly from provided information. However, other concepts required additional research to determine if a concept could be developed which would be of further value to the report.

Background Information

Some of the research ideas described in this report are being addressed to some degree, either by petroleum companies or by service companies. A recent forum, sponsored by the Society of Petroleum Engineers, was held on the topic of "Scientific and Engineering Impact on Environmental Regulations." No proceeding of the forum were printed; however, some of the topics discussed in the forum were as follows:

- Environmental Impact of Onshore Drilling Operations
 - Reserve pit environmental assessment
 - Traditional disposal technology and environmental liability
 - New trends in disposal technology
- Treatment and Disposal of Drilling Cuttings/Muds in Offshore Operations
 - Impact of offshore oil contaminated cuttings disposal and scientific criteria used to determine North Sea regulations
 - Oil-based mud disposal (OBM) and treatment options of OBM contaminated cuttings
 - Toxicity and environmental effects of fluids used in offshore drilling. The impact of future offshore regulations in the U.S.
- Surface Discharge of Produced Water
 - Nature of produced water and species to be removed
 - Naturally occurring radioactive materials (NORM)
 - Analytical techniques and chemical treatment
 - Equipment and processes for water treatment
- Ecological Considerations in Exploration and Production Operations
 - Exploration and production in coastal wetlands: direct and indirect effects of their mitigation
 - Ecological considerations - uplands
 - Diverse ecological conditions confronting operations in the U.S. OCS including response to oil spills
- Waste Minimization and Toxicity Reduction in Exploration/Production Operations
 - EPA's perspective on waste minimization in production operations
 - Toxicity reduction in E&P operations
 - Waste minimization in drilling and production operations
- Remediation of Contaminated Groundwater
 - Evaluation and remediation of contaminated groundwater
 - Discovery and assessment of petroleum contaminated groundwater systems
 - Groundwater monitoring and corrective action regulations: impacts, solutions, and future directions.
- Air Quality Issues Impacting Exploration and Production Operations

- California OCS air regulations: issues, technical requirements, and implications for other areas
- Toxic air contaminants emerging legislation: issues for industry, response, and technology requirements
- The Clean Air Act and potential reauthorization challenges and requirements for industry from a scientific and engineering aspect
- Protection of Groundwater During Underground Injection
 - Mechanical integrity testing and area of review
 - Logging methods
 - Risk assessment of potential damage to underground sources of drinking water
- Technology Needs for Tomorrow's Regulations
 - EPA groundwater, hazardous waste, and superfund technology research programs
 - Need for elimination of groundwater contamination

These are topics of interest to the exploration and production branches of the petroleum industry, not only in the United States, but on a national scale. These also are topics in which the petroleum industry is conducting research and development. DOE might better expend its resources on cooperative research with petroleum companies rather than having its own research program. This format would direct funding toward ongoing research that relates directly to the needs of the petroleum industry. This proposed method of directing public funding would also preclude spending time and effort on topics previously investigated.

Another area in which the DOE could play a leading role is technology transfer. A series of single issue symposia or workshops that bring together industry, academia, regulatory, and environmental groups to discuss existing problems, potential solutions, and the economic and social impact of those potential solutions would be helpful.

One of the themes discussed most frequently at the SPE Forum was the fact that science and technology can have only limited impact on environmental regulations. What is often more important is public perception of risks associated with certain industrial activities. Although the actual risk is

What matters to the environment, perceived risk is what motivates public and environmental regulators. The DOE could help in determining how to make real and perceived risks coincide.

Another theme discussed at several sessions of the forum was the use of technology-based regulations rather than risk-based regulations; for example, that a discharge must have no more than a specified concentration of a particular contaminant. Such regulations are relatively easy to monitor and enforce but might offer insufficient or excessive protection to the environment. To base regulations on risk, however, a knowledge of the toxicity of a discharge; the probability of organisms, including humans, coming in contact with the discharge; the probable duration of contact with discharge; and the probability of harmful effects from the discharge must be known. Such regulations are much more difficult to monitor and regulate but could provide more appropriate protection to the environment. Many of the participants at the forum expressed concern that current and potential technology-based regulations would place an unbearable burden on the petroleum industry without reasonable protection to the environment. DOE might be able to work with industry and environmental regulators in developing a protocol to determine appropriate risk-based regulations.

DESCRIPTION OF SELECTED ENVIRONMENTAL RD&D NEEDS

Brief Summaries of Selected Topics

This section consists of a brief summary of selected subject areas.

1. Better Aquatic Toxicity Test. Currently, mysid shrimp are used for testing. Testing takes 7-10 days. This test is also, subject to availability of shrimp.
2. More Information on Sublethal and Chronic Effects of Chemicals in Surface Water Discharges on Organisms at Different Levels of the Food Chain. A thorough knowledge of the effects of heavy metals could prevent regulation by the EPA and reduce future liability.

3. Development of Low Toxicity Drilling Fluids, Lubricants, Defoamers and Stuck Pipe Additives. If drilling fluids could be developed that contained lower levels of toxic chemicals or hydrocarbons, many of the present concerns regarding toxicity would not exist.
4. Improved Drill Solids Removal Process to Reduce the Volume of Drilling Fluid From a Well. Disposal of drilling fluids safely and economically is a major concern, especially in offshore sites.
5. Fate of Toxic Wastes. Many toxic chemicals are used in the production of gas and oil. The fate and transport of these chemicals has not been adequately evaluated.
6. Landfarming. This issue appears to be adequately researched. However, specific protocols or specifications are not available.
7. Innovative In Situ Treatment Technologies for Cleanup of Contaminated Sites. An innovative technology/equipment that is potentially capable of implementing a range of in situ treatment methods.
8. Well Integrity Maintenance Using Pumpable Solvents. Well mechanical integrity is of prime importance. Methods are discussed in this reference that enable sealing of failed wells in situ.
9. New Completion Fluid/Workover Fluids. A fluid is described in this reference that should provide extended life to well casing. The fluid is very stable at elevated temperatures.
10. Bioremediation - There are a number of references for this procedure. Some use microbes to remove contamination, others refer to cloning of new bacteria.
11. A Preliminary Examination of the Laboratory Sheen Test. Current EPA regulations use only visual observations for evidence of free hydrocarbons. A method is needed to quantitatively detect free hydrocarbons at offshore platforms.
12. Necessity Inspires Oil Patch Innovators. Drilling innovations needed are noted: (1) improved control over cementing, (2) prolonging the life of drill strings, and (3) improving pressure predictions.
13. Cleanup of Oil Field Wastes in an Environmentally Acceptable Manner. An innovative technology which through field testing has proven to be both cost-effective and an environmentally-safe disposal method.

14. Biological Methods for the Restoration of Contaminated Aquifers. This suggests that special bacteria (themselves nonpolluting) could be used to decontaminate aquifers polluted by hydrocarbons. See number 10.
15. Innovative Technologies for the Treatment of Hazardous and Mixed Wastes. Among innovative technologies being developed are: (1) supercritical water oxidation of hazardous chemicals, (2) microwave assisted destruction of chlorinated hydrocarbons, (3) paramagnetic separation of metals, (4) treatment/disposal of reactive metals, and (5) encapsulation.
16. A Corporate Waste Management Program. This suggests that a waste management protocol is needed for petroleum related waste disposal.
17. Radio Frequency Thermal Soil Decontamination. Radio frequency heating uses electromagnetic energy directed through electrodes in the soil, thereby heating the soil and driving off contaminants.
18. Solar-Powered UV/Thermal Treatment System. A system using solar energy to destroy hazardous organic wastes has been developed.
19. Method for Determining Waste Management - Including Future Liability. A comprehensive workbook that establishes procedures for evaluating all hazardous waste management cost has been developed. Software is included as part of the package.
20. Treating Hazardous Wastes By Reversible Gel Absorption. A new process called "reversible gel absorption" for concentrating aqueous waste streams is being tested. Initial results indicate that this method could be a cost-effective alternative to other methods.
21. Innovative Pressurized Liner System Reduces Leachate Transport. This new technique employs a pressurized clay liner system. Initial testing is being done.
22. Determining the Feasibility of In Situ Bioreclamation. This is a simple method that can be used to evaluate the feasibility of bioreclamation at a given site, based on information that is typically gathered during a remedial investigation.

The following concepts are taken from recent patents. Development of concepts from the patent stage often requires long periods of time before the product is brought to fruition. Patents should be viewed as being on the cutting edge of technology and sources for additional development.

23. Process and Apparatus for Eliminating Oil Field Waste Pits. A process and apparatus for eliminating oilfield waste pits is described.
24. Process and Composition for Removing Contaminants From Wastewater. A process to remove a number of contaminants from wastewater in the form of a nonleachable sludge is described.
25. Treatment of Oilfield Wastes. A method and apparatus of treating oilfield wastes and particularly spent drilling fluids containing barite and hydrocarbons is described.
26. Method and System for Treating Drill Cutting Slurries. A method to treat drill cutting slurries for environmentally-safe disposal is described.
27. Low Toxicity Oil-Based Drilling Fluid. A nonfluorescent, low-toxicity oil for use in oil-based or water-based drilling fluids.
28. Pollution-Free Well Cutting Disposal Apparatus. An apparatus that can be used for removing oil from drill cuttings at an offshore platform.
29. Treating Sludges and Soil Materials Contaminated with Hydrocarbons. A method is presented for cleaning soil contaminated with hydrocarbons.
30. Drill Cuttings Treatment. The object of this invention is to provide a new and improved method and apparatus for treating drill cuttings for disposal.
31. Apparatus and Method for Processing Oil Well Brine. An apparatus and process are described for controlled concentration of oil well brines.
32. Oxygen-Activation Log. A promising new tool that can be used for evaluating the mechanical integrity of injection wells.

EXPANDED CONCEPTS

This section consists of seven concepts that were judged to be worthy of further expansion according to the selection process shown in figure 2. Each expanded subject consists of the following:

- scope
- background
- current technology
- areas of concern not presently being addressed
- scope of work
- economics
- references

A. Subject

Mechanical integrity testing of injection wells by the oxygen-activation log.

Scope

A promising new logging tool used for evaluation of the mechanical integrity of injection wells is currently in the latter stages of development. However, because of economic restraints on the industry, the tool has not been accepted, and subsequent development is in question. It has been suggested by industry that the DOE's involvement in the development of the oxygen-activation log could provide the incentive to make a potentially valuable tool available to small independent producers. Without such incentive, the technology may not be successfully applied in the field.

Background

EPA is charged with the responsibility of protecting underground sources of drinking water from contamination by underground injection. The petroleum production industry's major involvement in underground injection is through secondary and tertiary oil recovery operations and disposal of produced brine. The wells involved are designated by the EPA as Class II injection wells. Class II wells must demonstrate mechanical integrity by the absence of leaks in the tubing and by having "no significant fluid movement into an underground source of drinking water through vertical channels adjacent to the

injection well bore." If an injection well has no cementing records or records which indicate inadequate cementing was performed, EPA has approved three logging tests to detect the presence or absence of flow behind the casing. The three tests are the temperature log, the noise log, and the radioactive tracer survey. In addition, EPA has granted interim approval, for two years from October 26, 1988, for the use of an alternative mechanical integrity test known as the Oxygen-Activation Method. The oxygen-activation method or log bombards the formation behind the casing with pulsed neutrons causing oxygen in the water to become a radioactive isotope. The radioactive isotope has a half-life of 7.13 seconds. Two detectors in the logging tool record the presence or absence of movement of the fluid behind the casing. According to industry personnel, the tool has technical merit for detecting channel flow, but has not yet been proven conclusively in the field. One industry specialist (from an operating company, not a logging service company) has recommended this tool as a candidate for DOE RD&D sponsored support.

Only one logging service company has a marketable oxygen-activation tool and another has one under development. However, according to an API committee representative, the logging service companies are not continuing to improve or further develop the tool because of lack of industry usage (sales). A major factor in the poor response by industry is the cost of running the log. It is not priced competitively with alternative logs and costs up to eight times as much as for other methods approved for fluid movement detection. Another reason offered for the lack of acceptance by the industry is that it is new and not many operators are aware of the log. The literature search bears this out to some extent. Only 10 references to the tool were found and five of these were patents.

API and EPA are jointly conducting a study to compare and evaluate temperature, noise, and oxygen-activation logs. Each log has its advantages and limitations; therefore, each log may fill technical gaps that the others do not cover.

The concern of one industry specialist is that a promising new logging technology will not be developed because of the economic depression of industry and because the public has not been informed of the advantages of this new technique. Their recommended goal for this logging method is to develop the tool and license it to the smaller logging companies. Thus, the

price would become competitive with alternative flowing fluid channel detection logs.

Current Technology

EPA has approved three logging methods to test for fluid movement behind the casing of Class II injection wells. The temperature log and the noise log will test for annular fluid flow from any source and the radioactive tracer survey will test for annular flow of the injection fluid. In addition, EPA has granted temporary, 2-year, interim approval for the oxygen-activation method. The oxygen-activation log, which produces a temporary radioactive isotope, will test for annular fluid movement from any source.

Areas of Concern Not Presently Being Addressed

A promising new logging tool, the oxygen-activation log, is currently being developed, which potentially will aid the industry in mechanical integrity testing of Class II injection wells. However, because of the economic depression of the oil industry, money and time does appear to be available for proper development of the tool. A representative of industry's user group (major oil company) has suggested this tool as a candidate for additional support. Involvement by DOE with both money and technology transfer could provide the means by which the tool could become available to the petroleum industry.

Scope of Work

The first area of concern is to continue development of the tool. Additional development of the tool could be accomplished by joint or federal funding of research and testing. Such funding would move future developments into the private sector (independent logging companies) much easier and quicker, thus improving the competitive situation.

Technology transfer is also needed to inform potential users of the capabilities of the oxygen-activation log.

Economics

Direct DOE involvement with this project could range from \$250,000 to \$500,000. However, it is suggested that DOE pursue the oxygen-activation log proposal on a cost-shared basis with several of the major oil companies and the tool manufacturer. This would also result in more effective technology transfer.

References

1. Williams, T. M. Measuring Behind Casing Water Flow, Subsurface Injection of Oilfield Brines. Int. Symp. Proc., New Orleans, LA, May 4-6, 1987, pp. 468-484.
2. Paap, H. J. Behind Casing Water Flow. Can. Patent 1,235,530, Appl. 503,620, Apr. 19, 1988.
3. Paap, H. J. Detection of Water Flow Outside A Well Casing. European Patent 236,613, Appl. 1986. Patent 301,899, Sept. 16, 1987.
4. deRosset, W. H. M. Examples of Detection of Water Flow by Oxygen-Activation on Pulsed Neutron Logs. Pres. at 27th Ann. SPWLA Logging Symp. Tran. Paper No. CCC, Houston, TX, June 9-13, 1986.
5. Paap, H. J. Behind Casing Water Flow Detection. U.S. Patent 4,580,050, Appl. 516,502, July 25, 1983.
6. Paap, H. J. Behind Casing Water Flow Detector. U.S. Patent 4,524,272, Appl. 451,635, Dec. 20, 1982.
7. Scott, H. d. and R. L. Campsey. Water Flow Well Logging Sonde and Method of Water Flow Sensing. U.S. Patent 4,486,658, Appl. 403,884, Dec. 4, 1984.
8. Wieseneck, J. B. Practical Experience with Oxygen-Activation Logging. Proceedings of the Int. Symp. on Class I and II Injection Well Technology, Dallas, TX, May 8-11, 1989, pp. 7-24.
9. Paap, H. J., T. W. Nussbaum and I. R. Supernaw. The Oxygen-Activation Log: A Laboratory Evaluation. Proceedings of the Int. Symp. on Class I and II Injection Well Technology, Dallas, TX, May 8-11, 1989, pp. 25-42.
10. Madden, M. P. and R. E. Porter. Costs of Logging Methods, DOE report SGP23-5, Feb. 1989.

6. Subject

A more rapid or alternative bioassay test for use in testing of offshore drilling fluids.

Scope

The current test for evaluation of offshore drilling fluids consists of a bioassay test using mysid shrimp. This test was developed by the Offshore Operators Committee Task Force on Environmental Science in cooperation with EPA Region II. The test is subject to a number of considerations including: (1) availability of shrimp, (2) long testing times, (3) expensiveness, and (4) failure during testing from variables other than the drilling fluids being tested.

Background

In the mid-1970s, the Offshore Operators Committee Task Force on Environmental Science working with EPA Region II (Mid-Atlantic) developed a drilling mud bioassay procedure which could measure the acute toxicity of a drilling fluid on a test population of organisms. Although a wide variety of marine species could be used, mysid shrimp (*Mysidopsis bahia*) was selected as the test organism. During testing, the shrimp are exposed to various concentrations of drilling fluids for 96 hours. The concentration required to kill 50% of the shrimp is calculated and termed the LC_{50} . A high LC_{50} value implies low toxicity, while a low LC_{50} value indicates high toxicity. Using this procedure, which became the accepted protocol for testing offshore discharges, the task force tested eight generic mud types generally used by the drilling industry in offshore environments and showed that generic muds exhibited low toxicity. In the general NPDES permit issued by Region II for effluent discharge in the Mid-Atlantic region, oil operators are limited to use of these generic muds without additional approval. If specialty additives are required in drilling operations, such as a lubricant, operators are required to submit toxicity data to the EPA which show that, in the concentration and usage required for the specialty additive, the toxicity of the mud system would not be greatly increased. Since the first general permit was issued in 1978, new general permits have been issued by other EPA regions which differ slightly from the original permit. Variations in permits occur because there

are no national standards on toxic pollutants and the best technology standards have not been well defined. Permits issued by Region IX for California, Region X for Alaska, and Regions IV and VI for the Gulf of Mexico have established an LC₅₀ value of 30,000 ppm as the toxicity limit.

In Region IX and Region X, the EPA requires operators to use the generic mud concept with an approved additive list. Prior to drilling a well, operators must submit a proposed mud program for approval. However, the EPA does not require the drilling fluid to be tested during actual discharge. In the 1986 general permit for the Gulf of Mexico, the permit sets toxicity limits for drilling fluids (30,000 ppm), prohibits discharge of diesel or any free oil, and requires bioassay testing every month and at the abandonment of the well. It appears that the other regions, such as Regions IX and X, will impose similar regulations.

Current Technology

Typical drilling fluids present difficulties when used for standard toxicity tests because of their chemical composition. Drilling fluids contain both water soluble and solid particles that can make physical observations during testing difficult. Another consideration is which fraction of the drilling fluid to which the organisms should be exposed. A pelagic organism would, in an offshore site, be exposed to a much different portion of the discharge plume than a benthic organism as shown in figure 3.

The EPA, in order to circumvent some of these toxicity testing problems, has adopted a protocol by which muds are separated into three phases that simulate offshore discharge. However, recent testing suggests that the separation of suspended particulates and solid phases of drilling fluids is in need of further evaluation and standardization. To provide interlaboratory calibration, a better method is needed to assure reproducibility of the technique. One method for classifying the suspended particulate phase would be to allow the slurry to settle for one hour and then to siphon 75 to 80% of the volume of the slurry from the particulate matter that has settled. The remaining particulates would be washed with seawater three to four times allowing a settling period between washes. The washes would simulate the effects of the particulates passing through a water column before reaching the bottom.

FIGURE 3. - Simplified characterization of drilling fluid discharge plume separation dynamics on the outer continental shelf.

The whole drilling fluids are generally more toxic than the individual phase separation and the organism's exposure is directly related to the plume's distance and direction from the point source and the position of the organism in relation to the water column. Current techniques only evaluate the toxicity of distinct phases of the discharge plume; however, future research may dictate the use of the whole mud for evaluation of its toxicity.

Areas of Concern Not Presently Being Addressed

The mysid bioassay toxicity test is the method that meets the approval of the EPA with regard to bioassay activity tests. However, the test does have several limitations: (1) requirements of long periods of time for testing; (2) expensive; (3) needs additional guidelines for definitions of solid phase and suspended particulate phase; and (4) subject to failure during testing from variables other than the drilling fluids being tested.

To provide a more rapid and accurate analysis of offshore drilling fluids, new testing procedures are needed to quantify the toxicity of offshore drilling fluids.

Scope of Work

Although the bioassay activity test is currently the method supported by the EPA, a new approach is needed. One such possibility is the adaption of an entirely new testing format. A toxicity procedure has been developed and proposed by the EPA for use in establishing acceptable initial loading rates and detoxification potentials for hazardous industrial waste when combined with soil. The procedure involves conducting toxicity screening and toxicity-reduction experiments using selected waste-soil combinations. The experiments employ a bacterial bioluminescence assay (Microtox™) to determine acute toxicities of organic contaminants contained in the water-soluble fraction of waste-soil mixtures. The Microtox™ technique is currently being evaluated by the oil industry as a possible technique to determine the toxicity of offshore drilling fluids.

Another recent alternative is an expert computer system that has been developed to approximate expected "lethal concentrations - 50% (LC₅₀) values based upon changes in concentrations of drilling fluid constituents. This program, developed by a service company, is based upon hundreds of laboratory-generated bioassay values. Use of the program reduces both the cost and time required to generate an indication of the LC₅₀ value expressed as a limited range.

The scope of this research project would be as follows: (1) to evaluate the three mentioned techniques for effectiveness, (2) determine if improvements could be made to the currently EPA approved bioassay test, and (3) pursue other research activities in this area that offer new and alternative testing procedures for the toxicity of offshore drilling fluids.

Economics

Full development of a new bioassay test would be dependent upon the results of the first phase of this project. Evaluation of the viability of the three techniques could range from \$50,000 to \$100,000. If one method is shown to be more accurate and reproducible, only incremental funding would be required. However, if this is not the case, full scale development of a new bioassay technique could cost up to several million dollars even with part of the work being cost-shared with industry.

References

1. Arscott, R. L. New Directions in Environmental Protection in Oil and Gas Operations. Pres. at SPE International Meeting on Petroleum Engineering Tianjin, China, Nov. 1-4, 1988, SPE Paper No. 17569, pp. 189-197.
2. Anonymous. Software Predicts Mud Toxicity. Oil and Gas J., July 11, 1988, p. 85.
3. Matthews, J. E. and L. Hastings. Evaluation of Toxicity Test Procedure for Screening Treatability Potential of Waste in Soil, Toxicity Assessment: An International Quarterly, v. 2, pp. 265-281, 1987.
4. Hanson, P. M. and F. V. Jones. Mud Disposal, An Industry Perspective. Drilling International, May 1986, pp. 16-21.
5. Breteler, R. J., A. G. Requejo, and J. M. Neff. Acute Toxicity and Hydrocarbon Composition of a Water-Based Drilling Mud Containing Diesel Fuel or Mineral Oil Additives, Chemical and Biological Characterization of Sludges, Sediments, Dredge Spoils, and Drilling Muds. ASTM STP 976, Philadelphia, 1988, pp. 375-390.
6. Brandsma, M. G., L. R. Davis, R. C. Ayers and T. C. Sauer, Jr. A Computer Model to Predict the Short Term Fate of Drilling Discharges in the Marine Environment. Proceedings, Symposium on Research on Environmental Fate and Effects of Drilling Fluids and Cuttings, Lake Buena Vista, FL, Jan. 21-24, 1980, v. 1, pp. 588-610.
7. Gaetz, C. T., R. Montgomery and T. W. Duke. Toxicity of Used Drilling Fluids to Mysids (Mysidopsis Bahia). Environmental Toxicology and Chemistry, v. 5, 1986, pp. 813-821.
8. Pierce, R. H., D. C. Anne, F. I. Saksa, and B. A. Weichert. Fate of Organic Compounds From Spent Drilling Fluid Discharged Into the Sea. In: Wastes in the Ocean, Energy Wastes in the Ocean, v. 4, Wiley, New York, 1985.
9. Technical Resources, Inc. Assessment of Environmental Fate and Effects of Discharges From Offshore Oil and Gas Operations. EPA PB86-114964, August 1985.

C. Subject

The drilling industry is in need of an environmentally acceptable drilling fluid additive which has the lubricating qualities of crude oil/diesel, or oil-based drilling fluids, but which are no longer considered environmentally safe.

Scope

According to industry sources, restrictions on use of oil based drilled muds or additives have resulted in abandonment of drilling pipe if stuck pipe is encountered. This requires additional time and expense. Prior to current regulations, the sticking was often relieved by spotting a petroleum-based liquid around the stuck zone. Current regulations do not allow contaminated cuttings or mud containing hydrocarbons to be disposed in the sea. Thus, when hydrocarbons are added to the mud system, the cuttings must be cleaned or hauled to shore for disposal. Both options are expensive, and development of an environmentally approved mud that would have the lubricating qualities of a crude oil/diesel-based mud is needed.

Background

Oil and oil-based fluids have been used for many years in the petroleum industry as completion fluids and, in special applications, in conjunction with drilling muds. In connection with drilling fluids, oil-based muds are emulsified to provide weight suspension and fluid-loss characteristics necessary for proper drilling mud performance.

These oil-based fluids are used for special drilling situations such as stuck drill pipe. When the drill pipe becomes stuck, an oil-based fluid can be spotted around the stuck zone, providing lubrication to aid in freeing the drill pipe. In development wells, where the potential for sticking is known to exist, an oil-based drilling mud system is normally used to prevent or minimize potential problems.

Other than as an aid in freeing stuck pipe, oil-based drilling muds provide additional advantages. Oil-based fluids are generally less damaging to producing formations, especially sensitive formations. An exception to this would be a water-wet production zone which could be damaged by oil

filtrate. Oil-based muds are also advantageous in coring, running liners, and reducing the drag on drill strings during routine operations.

Current Technology

With the enactment of recent environmental regulations, the use of an oil-based drilling fluid offshore is no longer an economic option. Therefore, a need exists to develop drilling fluids which provide lubrication characteristics of oil-based mud systems without environmental risk.

In recent years, an alternative drilling fluid has been developed which is generically referred to as a mineral-oil-based fluid. This drilling fluid is claimed to have maintained the positive characteristics of oil-based fluids but is much less toxic. How this fluid responds to the "sheen" test is not mentioned in the literature.

A recent patent claims to have developed a low-toxicity oil for use in drilling fluids. The patent claims the fluid also does not have a water sheen nor does it mask ultraviolet fluorescence of formation crudes. The patent does not mention whether or not lubrication characteristics have been improved upon in the development of this fluid.

Areas of Concern Not Presently Being Addressed

According to the literature survey and industry contacts, work is being done in this area; however, problems still exist. The drilling sector apparently still does not have a drilling fluid to use in case of stuck pipe and other circumstances where only oil-based materials will work. EPA has approved generic muds; however, proven drilling fluids to work in these special circumstances apparently are still not available.

Scope of Work

Collect information on drilling fluid products available as alternatives to oil-based drilling muds. This would require contacting mud service companies, drilling contractors, and operators.

Standard laboratory toxicity and sheen tests should be run on any products which claim to provide the benefits of oil-based fluids and be environmentally safe. Access to analysis of these products previously done by independent laboratories would reduce the number of required tests.

Field testing and evaluation of products that pass toxicity and sheen tests could be accomplished by obtaining access to drilling records for rates of penetration, bit usage, torque, fuel consumption, and incidence of stuck pipe or other problems while using conventional drilling fluids. Then on a similar hole, from the same platform, drill a well using a mineral-oil-based fluid and collect the equivalent data. The cost of such a project to the DOE should be relatively nominal, assuming the sponsor would only pay for the additional cost of the special mud additives program.

The results of such a testing program would be published and presented at appropriate industry meetings.

The ultimate goal of such a project would be to develop and prove the product and to obtain EPA approval to include the developed nontoxic fluids as additives to their "approved generic mud" list.

Economics

If the new fluids described under this subject are capable of meeting standards as set forth, only minimal funding would be required. This would still require comparison to presently available spotting fluids, EPA approval and marketing. DOE cooperation with one or more of the major service companies would result in a minimal outlay (\$50,000 to \$150,000). This does not include the price of drilling the well.

References

1. Arscott, R. L. New Directions in Environmental Protection in Oil and Gas Operations, J. Pet. Tech., April 1989, pp. 336-342.
2. Bennett, R. B. New Drilling Fluid Technology - Mineral Oil Mud. J. Pet. Tech., June 1984, pp. 975-981.
3. Boyd, P. A. Low Toxicity Oil-Based Drilling Fluid, U.S. Patent 4,787,990, Appl. 463,779, Nov. 29, 1988.

Subject

Bioremediation/Biodegradation of Hydrocarbon Contaminated Environments.

Scope

The use of microbes to biodegrade petroleum related hydrocarbons is a viable technology which is currently on the forefront of research in the scientific community. However, the use of microbes as a method of decontaminating sites contaminated with petroleum hydrocarbons has not advanced to the stage where the technology is readily available. Additional means for technology transfer and research are needed to put this technique within reach of the oil industry.

Background

Bioremediation or biodegradation of most forms of waste contamination (including petroleum) usually occurs naturally from indigenous organisms, which are present nearly universally, when the environmental factors are suitable (i.e., nutrients, moisture, oxygen, temperature, pH, etc.). The proliferation of petroleum wastes, with the increased activity in petroleum drilling, production, refining, transport, and usage, have resulted in contaminations which cannot be tolerated by the public or left to nature to remediate.

As a result, much attention is being focused on cleaning up hydrocarbon contamination of the environment. Biological treatment is not the only method which has been developed for a wide range of hydrocarbon contamination sources, from drilling to the gasoline retail sales point. However, bioremediation is a method which has the potential to clean-up hydrocarbon contamination with minimal impact to the environment.

It is apparent that much work is being done in this area; however, the bulk of the work is being done in the laboratory and involves developing and isolating microorganisms which will decontaminate specific hydrocarbons. A few descriptions of actual field projects are discussed in the literature but most involve restoration of contaminated aquifers, without reference to decontamination of soil.

Current Technology

Much work is being done in the laboratory to develop microorganisms for bioremediation; however, the literature indicates more work is needed. One reference states, "Environmental modification...such as that achieved by aeration or fertilization with nitrogen and phosphorus has not been shown to enhance biodegradative removal of hydrocarbons." Another states, "It can be concluded from an examination of experimental data and a review of the scientific literature that successful biological treatment of oilfield wastes has not been achieved or reported to date."

Several references indicate that a major obstacle to bioremediation is the application of the technology. One reference states, "the translation of our scientific knowledge of hydrocarbon biodegradation into practical application remains a major challenge." Another, discussing in situ reclamation, states, "However, practical experience in the design and implementation of biological treatment systems is limited."

Areas of Concern Not Presently Being Addressed

While much work is being done, a concerted effort and transfer of technology does not appear to be occurring in the area of bioremediation. A means of defining the actual contributions that can be made by means of bioremediation is needed. This can be achieved by setting a realistic goal for initial proving and testing of specific bioremediation techniques. Currently, there is work being done regarding bioremediation of waste pits. It is suggested that this would be an area to comprehensively evaluate bioremediation as a viable technique for application to the petroleum industry.

Scope of Work

Waste pits are not readily amenable to conventional closure methods because of high oil concentrations and solids handling. Each oil-producing state has varying regulations regarding waste pits. Some initial work has been done regarding the use of biotechnology for the elimination of hydrocarbon contamination. However, technology transfer and specific methods for application of biotechnology in this area are not readily available and are not fully developed.

The DOE could provide impetus to this potentially viable technique. This could come in the format of a defined methodology for elimination of waste pits using microbes. This would be achieved by compiling present knowledge and then funding a specific research project. Information that would be gathered during the two research phases would include:

1. A catalog of microbes amenable to the process.
2. Nutrients, water and oxygen requirements.
3. Temperature requirements.
4. pH requirements.
5. Hydrocarbons capable of being metabolized.
6. Source of microbes.
7. A cost comparison to other methods.

Once this type of information is available and analyzed, the next step would be technology transfer, if the techniques proved to be environmentally and economically viable.

Economics

Since this is an emerging technology area, investment could be high. However, initial work has been done in many areas of research that are necessary to make bioremediation technologically successful. Also, specific research is being done in this area noted. Additional laboratory and field tests are needed to prove this technique. DOE involvement on a cost-shared basis could range from \$200,000 to \$1,000,000. This should be weighed against the large number of waste pits present that are in need of remediation and the cost involved using present methodology.

References

1. Marks, R. E. and A. Wojtanowicz. Biodegradation of Oil-based Drilling Muds and Production Pit Sludges, J. Energy Resources Tech., v. 110, Sept. 1988, pp. 183-188.
2. Watson, J. S. and C. D. Scott. The Impact of Bioprocessing on Enhanced Oil Recovery, Oak Ridge National Laboratories. Dept. of Energy Report No. DE88-006985, March 1988, pp. 55.
3. Atlas, T. M. Biodegradation of Hydrocarbons in the Environment. Environmental Biotechnology, 1988, pp. 211-222.

4. Field, S. D., L. Forbes, R. E. Marks, and A. K. Wojtanowicz. Biological Treatment of Oilfield and Petrochemical Hazardous Wastes. Pres. at the Engineering Foundation Conf. on Biotechnology Applications in Hazardous Waste Treatment, Longboat Key, FL, Oct. 30-Nov. 4, 1988.

5. Marks, R. E., S. D. Field and A. K. Wojtanowicz. Oil Reduction in Drilling Wastes By Biological Treatment. Pres. at 2nd Oklahoma Univ. Drilling Muds National Conf., May 28-29, 1987, pp. 78-104.

6. Galaska, E. G., G. J. Skladany, and E. K. Nyer. Biological Treatment of Groundwater, Soils, and Soil Vapors Contaminated with Petroleum Hydrocarbons. Pres. at the 44th Ann. Purdue Industrial Waste Conf., West Lafayette, IN, May 10, 1989.

7. Torpy, M. F., H. F. Stroo, and G. Brubaker. Biological Treatment of Hazardous Waste, Pollution Engineering, v. 21, No. 5, May 1989.

8. Glaser, J. A. Promising Technologies for the Biological Detoxification of Hazardous Waste, EPA/600/D-88/040, February 1988, 12 pp.

9. Cheremisinoff, P. N. Water and Wastewater Treatment-Fundamentals and Innovations, Pollution Engineering, March 1989, pp. 94-99.

Subject

A more efficient method for technology transfer of environmental RD&D needs.

Scope

There is an abundance of information available regarding the environment. This occurs in the form of publications, symposia, patents and other means of communication. There is also an increased awareness of the environment and in conjunction additional regulations and restrictions are being improved. Perhaps because of all of this activity being generated there appears to be a technology transfer gap in the area of petroleum related environmental research. Pertinent environmental information regarding advances in this area is not being directed at those who need it.

Background

Environmental concern has been on the forefront in the United States for the past 20 years at the federal level. New agencies have been created and a number of major environmental laws written and amended along with a number of regulations being issued by federal agencies. However, according to one author there are still major environmental challenges facing the petroleum industry in the near future. They include:

- Developing better scientific information, technologies, and analytical techniques to solve environmental problems.
- Improving public access to information on petroleum operation and products.
- Linking environmental protection with other important national goals.
- Develop and articulate a strategy to participate more effectively in the public debate over environmental policy and devise constructive solutions in partnership with the government and citizenry.

Another dilemma that is facing the oil industry is the large cutbacks that have been required because of lower oil prices. In many cases, the first areas to be deleted include those directly related to technology transfer such as meeting attendance, presentation of papers, and in, some cases availability of job-related information.

Current Technology

There are a number of avenues by which technology transfer occurs such as symposia, publications, patents, in-house training, and other equally efficient means of communication. However, with the flood of information that is available, sometimes it is not possible to properly access all sources adequately to evaluate a given technique. The smaller independent oil companies do not have the proper facilities available to stay abreast of current technology. In some cases, the larger companies have been forced to cut back on this type of activity because of lower profit margins. A typical example of an activity much as described herein is the Reservoir Characterization Symposium held bi-yearly by NIPER and sponsored by DOE. A workshop is held in conjunction with the symposium and is a DOE deliverable in this project.

Areas of Concern Not Presently Being Addressed

Technology transfer is available and does occur; however, focus has not been directed towards specific environmental RD&D needs facing the oil industry. The petroleum industry is directly tied to environmental regulations and their applications. To adequately and properly address these environmental regulations and changes, the industry as a whole must be aware of current technology developments in the environmental area.

Scope of Work

The EPA, API and various oil companies have a number of committees and groups that are involved in current development, regulation, and research related to the environmental area. However, the best possible means of dealing with environmental problems may be left up to one individual in that corporation. The purpose of this task would be to make available current developments in the environmental RD&D area so that the best available options are taken by that individual(s). This could occur by means of several different formats; however, the one suggested for this report includes the use of workshops and an on-line database to provide the best options.

The suggested workshop would be similar to a symposium, but on a more informal basis. Initially, this would be a panel of selected environmental specialists from environmental groups, industry, academia and government

including DOE planning staff. The panel would be assembled and directed toward the goal of making the petroleum industry aware of specific environmental RD&D. This could occur as a sideline to a national SPE meeting for convenience and would be held on a yearly basis. Much of the information transfer could be advertised in technical and trade journals. The information transfer also could be set up on a computer data base making it readily available either on-line or by purchase of disks. This would also result in rapid updating. Related information from this report could be used as a typical format. DOE could be responsible for the initial arrangements with minimal funding and then let the petroleum industry take it over after the system has been proven functional. Each workshop could be devoted to a single topic of interest, i.e., policy, offshore, air, natural radioactive produced water, etc. Prior to the workshop, representatives would be solicited that are knowledgeable in the area to be discussed, as is done for the SPE forums, along with input for subtopics to be covered.

References

1. Yosie, T. F. Environmental Challenges Will Need Cooperative Solutions, Oil and Gas Journal, Nov. 14, 1988, pp. 59-63.
2. Executive Office of the President, Council on Environmental Quality. Report of Long-Term Environmental Research and Development, March 1985.
3. The Interstate Oil and Gas Compact and Committee Bulletin: The 1988 Annual Meeting, Overland Park, KS. Dec. 4-7, 1988. v. II, No. 2.

F. Subject

A comprehensive waste management protocol for the oil and gas industry.

Scope

In light of current governmental regulations, a specific protocol or guidelines would be valuable to operators considering startup of a process that involves waste management. Such a protocol would be instrumental in not only defining wastes, but would also provide data that would predict possible reaction products. Another phase of the protocol would provide risk assessment and predict potential future liability.

Background

The large number of regulations concerning waste disposal and public awareness impose new burdens on the oil and gas industry regarding wastes generated. Increased disposal costs also necessitate that changes in attitude are made regarding waste disposal. Some of the major challenges facing the oil industry include developing better scientific information, technologies, and analytical techniques to solve environmental problems.

Past attitudes regarding wastes have been to wait until a problem exists with the waste(s) and then determining what can be done about the waste (Exxon Valdez - a prime example). Policies and plans may be in place; however, enactment is another question.

Any type of waste generated by the oil and gas industry must be assessed with a new perspective in light of current regulations and restrictions. The oil and gas industry needs to evaluate each phase of its business to include that portion of their business which deals with wastes while they are being generated. Not only should the wastes produced be studied, but also the process by which the wastes are produced. An overall waste management program should evaluate the whole picture including solids control, survey management, waste water reuse, waste water disposal and solids disposal.

Development of a totally comprehensive waste management program would result in a more economical use of facilities and be of benefit to the environment. In the case of unexpected situations (accidents, leaks, spills, etc.), an estimation of any future liabilities regarding the wastes would lessen the impact.

Current Technology

Current activities regarding disposal of wastes addresses the continued implementation of programs under the Resource Conservation and Recovery Act (RCRA), as well as regulation promulgated by state authorities which in some cases are more stringent.

Some companies have begun to evaluate projects with the approach of not just dealing with the wastes generated, but detailed evaluation of the process that generates the wastes. One such company has applied this approach to developing and implementing a waste management plan for a large scale drilling project. Recommendations also are noted to refine this plan for future projects.

Another firm, unrelated to the oil industry, has developed a plausible method for estimating true hazardous waste management costs. Even when wastes are managed onsite, unplanned expenses can occur if corrective actions are required to clean up releases from units such as leaking surface impoundments. The protocol will not only result in waste minimization, but also will fully account for the future liability of many hazardous waste management methods.

Areas of Concern Not Presently Being Addressed

In some cases, the approach in major industries, including the oil and gas industry, is to ignore a situation until forced to act upon it. This has certainly been the case for the disposal of most wastes in all industries. Most waste disposal problems have been noted after the fact. The trouble with this type of approach is that remediation then requires more time and energy as compared to a properly planned procedure of action. Evidence has been noted of a change in corporate attitudes regarding waste disposal and environmental issues. This is in part due to the emphasis being placed on environmental regulations by the EPA and others.

There is a need for comprehensive management of waste disposal. Our work indicates that preliminary work is being done in this area. However, the importance and cost saving relationships of such a program are not generally available. Transfer of recently developed techniques and methods need to be applied to wastes associated with the oil and gas industry.

Scope of Work

The scope of work for these tasks is twofold since work has been already initiated in this area. The first step is to fully utilize current technology and methodology in formalizing a protocol for waste management as related to the oil and gas industry. Secondly, the industry must be made aware of the benefits of overall waste management. The developed waste management protocol would entail the following main objectives:

- Minimize the volume of waste generated.
- Treat and reuse as much waste as possible (dependent upon process).
- Dispose of all remaining wastes in an environmentally acceptable and economical manner.
- Provide a means of risk assessment.
- Provide a means for determining any potential future liability.

Economics

At issue for this proposal is not if, but when the capital outlay will be made. If costs and waste management are determined at the onset of large scale projects, the total outlay and environmental impact could be minimized. DOE involvement in this proposal would be more in the technology transfer area to assure that the petroleum industry is aware of the potential benefits.

References

1. Yosie, T. F. Environmental Challenges Will Need Cooperative Solutions. Oil and Gas J., Nov. 14, 1988, pp. 58-63.
2. Anonymous, G. E. Develops Method For Determining True Costs of Waste Management - Including Future Liability. The Hazardous Waste Consultant, March/April 1988, pp. 1-1 to 1-3.
3. Davies, G. E. and J. H. Wensley. Waste Management For a Large-Scale Drilling Project. J. Canadian Pet. Tech. March/April, 1987, pp. 44-51.

G. Subject

A Pollution Potential Prioritization Protocol for Abandoned Wells.

Scope

At present, no systematic procedure or protocol is available to:

- (1) provide information on abandoned wells,
- (2) evaluate environmental and economical impact of abandoned wells,
- (3) provide information related to the mechanical integrity of abandoned wells,
- (4) provide reliable means of plugging abandoned wells or for conversion to injection wells, and
- (5) provide technology and information transfer.

Background

Abandoned wells can serve as conduits for the transport of pollutants from saline or otherwise polluted geological zones to fresh water aquifers. It is conservatively estimated that approximately 2 million oil and gas wells have been abandoned in the United States since the first well was drilled 125 years ago. Numerous isolated examples of the influence of abandoned oil and gas wells in causing ground water pollution can be cited even though no nationwide systematic study has been conducted to ascertain the nature and extent of ground water quality problems resulting from abandoned wells. The U.S. EPA made public its Regulatory Determination on June 30, 1988. In the determination, the EPA listed examples of waste treatment methods and general field practices which in specific instances have not been used in an environmentally sound manner. At issue are not the practices themselves, but the lack of state regulations for oversight of the practices. One issue cited was abandonment practices (existing and previously abandoned wells).

Current Technology

The history of plugging abandoned wells dates back to 1899 when in the State of Texas a \$100 fine was to be imposed for failure to case or plug wells in accordance with state statutes. However, enforcement of such laws was probably not strict, and there is the possibility of contamination from wells that were plugged 50 to 75 years ago even if the procedure was properly done

according to the technology of the time. The American Petroleum Institute has three recommended practices directed toward plugging and abandonment: RP51, RP52, and RP57. Several articles found in the literature search describe the current technology but point out that additional research is needed. The U.S. EPA is conducting (1989) research to determine what materials are adequate for plugging wells, to develop techniques to enter previously plugged wells, and to determine the efficiency of plugging materials.

Areas of Concern Not Presently Being Addressed

A provision of the RCRA was that wastes generated by oil and gas exploration operations be given special consideration. The RCRA amendments subsequently directed the EPA to study such wastes and recommend appropriate regulatory action to Congress. The U.S. EPA made public a Regulatory Determination on June 30, 1988, that cited abandonment practices as a specific field practice that has not been used in an environmentally sound manner. It is evident that problems exist in this area, and additional work is needed. A protocol to prioritize the pollution potential of abandoned wells would have both an economic and environmental impact on oil and gas production operations. Solutions to this complex problem could possibly protect operators from liability charges and also permit more control over field operations. In addition, possible contamination that could occur from abandoned wells would be prevented.

Since abandoned wells occur in such a large geographical area encompassing a number of states, an integrated format would provide the best results. If primacy is granted to states in such a matter, a program of this nature could not possibly be fully and adequately developed. DOE involvement would enable a program of this nature to be developed to its fullest.

Scope of Work

This protocol would be utilized and applied when operators are to initiate new production changes in a field. It also would be applied in the event of contamination or leakage of an existing abandoned well. The protocol would be similar to an environmental impact survey. Developed methodology would specify techniques for locating abandoned wells, techniques for plugging abandoned wells to prevent future environmental contamination, and procedures to be used

to convert abandoned wells into environmentally safe injection wells, if that is the case. Another situation where the protocol could apply would be in the event of contamination or leakage of an improperly plugged or unknown abandoned well.

The EPA and others have initiated research in this area. The developed protocol would rely heavily upon available information to prevent redundancy. Initially, a data base of abandoned wells would be developed in those areas where most oil field activity occurs. It would perhaps be impossible to provide a complete data base of all abandoned wells because of the large number of wells that have been drilled and abandoned in the past 125 years. Another section of the developed protocol would provide specific tests to evaluate the integrity of abandoned wells. Standard procedures for permanently plugging or for converting abandoned wells into environmentally safe injection wells would complete another phase of the protocol.

Full development of the protocol would include a risk assessment category. This section could be a type of simulator or model that could predict the probability and severity of pollution resulting from a particular well or wells having similar characteristics (based upon age of well, reservoir heterogeneities, existence of plugging records, and other well history). In addition, the protocol would consist of a means for technology and information transfer. This would be available in a printed format with detailed information regarding remediation of abandoned wells.

Economics

To accomplish all phases of this work is probably not economically possible. However, many phases of this work are in place requiring smaller amounts of capital investment. This protocol could be initially attempted only in one state and later expanded, if proven worthwhile. Initial investments could be in the \$250,000 to 1 million dollar price range. Another consideration is the cost that would be required to clean up a fresh water aquifer that is a water supply for a large city, if contamination or pollution occurs because the above steps were not undertaken.

References

1. Canter, L. W. Problems of Abandoned Wells. Pres. at the First Nat'l. Conf. on Abandoned Wells: Problems and Solutions, Norman, OK, May 30-31, 1984.
2. Smith, M. D. Feasibility Study of the Effectiveness of Drilling Mud as a Plugging Agent in Abandoned Wells. Robert S. Kerr ERL Blue Book, 1988, p. 84.
3. Warner, D. C. Abandoned Oil and Gas Industry Wells and Their Environmental Implication. Pres. at the UIPC Summer Meeting, Portland, OR, July 31-Aug. 3, 1988.
4. Madden, M. P., J. F. Pautz, and R. D. Thomas. Plugging and Abandonment Methods. Dept. of Energy Report No. SGP23-1, Oct. 1988.
5. Madden, M. P., J. F. Pautz, and R. D. Thomas. Survey of State Class II Programs: Task 2 - Plugging and Abandonment. Dept. of Energy Report No. SGP23-2, Nov. 1988.
6. American Petroleum Institute, API Environmental Guidance Document. Jan. 15, 1988.

III. CONCLUSIONS AND RECOMMENDATIONS

This project was designed to aid the Department of Energy in delineating areas of future research in the petroleum related environmental area. A major concern was that the identified needs not only have the potential to improve the performance of the oil and gas industry but accomplish this task in such a manner that would prove economically and environmentally beneficial. These objectives were met by (1) means of a literature search that identified environmental areas that are of concern to both the major oil companies and smaller independents, (2) contact with environmental specialists in industry, academia and government, (3) attendance of related environmental forums and symposia, and (4) in-house panel meetings. Results of these means of obtaining project related information indicated over 33 individual areas that were directly project related.

Discussion of these identified areas by means of an in-house panel and personal and telephone contacts with environmental specialists resulted in the following seven topic areas chosen for expansion. The topics are prioritized in order of importance and include:

1. Oxygen-activation log which would be used to determine if fluid flow is occurring in the well annulus,
2. Alternative bioassay test to quantify and assure toxicity levels of offshore drilling fluids,
3. Environmentally safe drilling fluid to be used in the event of stuck pipe or similar circumstances,
4. Bioremediation of waste pits using the latest biotechnology developments to clean/remediate oilfield waste pits.
5. More efficient means of technology transfer in the environmental area to ensure that the latest in environmental techniques and information is readily available,
6. Comprehensive waste management to evaluate waste produced and determine the best technique for reduction and/or disposal, and
7. Pollution prioritization protocol for abandoned wells which would aid in defining the economical and environmental impact of abandoned wells.

**APPENDIX A -- Annotated Bibliography of Papers Related
to Environmental RD&D Needs.**

- 1) **Arscott, R. L. New Directions In Environmental Protection In Oil and Gas Operations, pres. at SPE International Meeting on Petroleum Engineering, held in Tianjin, China, SPE 17569, pp.189-197, Nov. 1-4, 1988.**

ALSO: Journal of Petroleum Technology, pp. 336-342, April 1989.

ABSTRACT:

Since the passage of the National Environmental Protection Act in 1970, the oil and gas industry has made tremendous progress in developing techniques, procedures and less toxic materials for the protection of human health and the environment. The toxicity of drilling fluids and their disposal is tightly controlled to minimize the effect on the environment. Waste management programs are becoming more common to reduce the generation of waste and to recycle waste products. Numerical models are available to simulate discharge dispersion in marine environments. Toxicologists have produced a large database on the effect of toxins in the environment, and more information is being developed on the effect of toxicants on native aquatic species and on the complete food chain. Cooperative agreements between industry, government agencies, environmental groups and others are becoming more popular to develop acceptable mitigation procedures.

Since the passage of the National Environmental Protection Act in 1970, the U.S. oil and gas industry has made tremendous progress in developing techniques and practices to improve the protection of human health and the environment. Tests for toxicity of drilling fluids are conducted routinely, and many exploration and production operations are modified to protect valuable wildlife and fisheries resources. The industry is cooperating with government agencies and environmental groups to conduct studies to improve our knowledge of the impact of operations on the environment and to develop appropriate mitigation plans.

Specific problems requiring further work are:

A more rapid aquatic toxicity test for drilling fluids for use on offshore platforms since the current mysid shrimp test takes about a week to get results;

More information on sublethal and chronic effects of chemicals in surface water discharges on organisms at different levels of the food chain;

Development of low toxicity drilling fluid lubricants, defoamers and stuck pipe additives;

Improved drill solids removal processes to reduce the volume of drilling fluid used for a well; and

Methods of cutting offshore platform legs with minimal adverse effects on endangered species

- 2) **Jones, F. V., C. M. Moffitt and A. J. J. Leutermann. Drilling Fluids Disposal Regulations, A Critical Review, Drilling, pp. 20-24, March/April 1987.**

ABSTRACT:

Concern over potential environmental impacts and new and pending regulatory changes will substantially impact both offshore and onshore drilling. With the reduced cost of oil and the increased expense of drilling new and more remote reserves, regulatory compliance will become a more significant part of the drilling process.

- 3) **Campbell, B. Offshore Muds Must Accommodate New Environmental Regulations, American Oil and Gas Reporter, v.30, no.8, pp.12,14,16, Aug. 1987. (ISSN. 0145-9198)**

DESCRIPTION:

EPA has imposed a LC50 of 30,000 ppm. for drilling mud discharge.

ABSTRACT:

To comply with current regulations the oil industry is using a bioassay test which can take up to a 7 day turn around. The cost/day if the test fails is \$10,000/day. A new device is being evaluated that can perform the test in two hours at a cost of \$200. Standardization/development of this test would be of immense value to the drilling industry while providing both economic and environmental relief.

- 4) **Anonymous. Software Predicts Mud Toxicity, Oil and Gas Journal, p. 85, July 11, 1988.**

ABSTRACT:

An expert computer system has been developed to approximate expected "lethal concentration - 50%" (LC₅₀) values based upon changes in concentrations of the drilling fluid constituents. Prior to disposal of drilling fluids and cuttings from an offshore rig or platform in the Gulf of Mexico, an operator needs to be confident that the discharge of these materials meets the LC₅₀ requirements of the National Pollutant Discharge Elimination System (NPDES). Currently, the limiting LC₅₀ value is 30,000 ppm of a suspended particulate phase (SPP).

- 5) **Executive Office of the President, Council on Environmental Quality. Report of Long-Term Environmental Research and Development. March, 1985.**

ABSTRACT:

Although non-specific this report impacts many areas of our environmental RD&D project.

A number of recommendations were made by this Council and include:

Monitoring - It was recommended that CEQ foster an evaluation by an appropriate organization of existing physical, chemical, and biological monitoring to identify and stimulate research and development on improving the quality and cost-effectiveness of monitoring programs.

Institutional Capability - It was recommended that attention be given to reaching sources of environmental and health research funding and ideas from the private sector to the extent possible. Also effort should be given to coordinating government sponsored research with research performed or supported by industry-specific organizations.

Hazardous Waste Sites - It was recommended that government agencies, particularly EPA and DOD, integrate well-defined research studies into plans for measurement and remedial action programs at selected hazardous waste sites. **Intermediate Transfer** - It was recommended that studies to determine intermediate transfer rates for both description and prediction of the subsequent fate of toxic chemicals in the environment.

Assimilative Capacity - It was recommended that research be undertaken to determine the behavior and biological effects of chemicals in environmental media as a basis for setting levels of release for protection of human health and environmental quality.

- 6) **Anonymous. Looking After the Environment, The Oilman, pp. 44-47, Nov. 1986.**

SUBJECT:

Removal of heavy metals or organics from drilling fluids.

ABSTRACT:

A dewatering process that removes heavy metals or organics from drilling mud is described. Removal of heavy metals or organics from drilling mud would remove toxic components and chemical oxygen demand from drilling fluid and permit it to be safely disposed of in a stream or lake.

- 7) **Tucker, B. B. Soil Application of Drilling Wastes, pres. at Okla. Univ., et. al., Disposal of Drilling Wastes National Conference, Norman, Okla., pp. 102-112, May 30-31, 1985.**

ABSTRACT:

Land application of municipal, industrial, and mining wastes is becoming an increasingly attractive alternative as a safe method of disposal. The major constraints in soil farming of drilling wastes are salt constituents. Basic principles in soil science on behavior and reactions of salts are established. These principles allow the management of salts to retain soil productivity. Comprehensive studies on drilling waste disposal have confirmed earlier findings and established that heavy metals in drilling fluids pose few risks to health and the environment because the traces of heavy metals do not migrate. These studies also showed that oil field wastes are not classified as hazardous as defined by E.P.A. and that soluble salts, primarily sodium and chloride, are the major constituents in drilling fluids exhibiting adverse effects on plant growth. Case studies of soil farming of drilling wastes in Oklahoma are presented which prove that they can be applied without harmful effects on soil productivity.

- 8) **Kissock, D. C. Landfarming: the Cost Effective State-of-the-Art Solution to Oilfield Waste Disposal, pres. at Okla. Univ., et. al., Drilling Muds National Conference, Norman, Oklahoma, pp.172-177, May 29-30, 1986.**

ABSTRACT:

The fate of nonhazardous oilfield wastes has become an important issue in recent years throughout the Gulf Coast Region. Each state in this region has enacted regulations to try to ensure the safe transportation and disposal of oilfield wastes, while concurrently satisfying the concerns of both the general public and industry. Of all the waste disposal alternatives developed, land treatment or "landfarming" provides the most favorable combination of disposal cost, short and long-term liability to the generator, and potential environmental impacts.

Land treatment is defined as the application of wastes into the soil surface to degrade, transform, or immobilize the waste constituents. Landfarming is, therefore, one of the few technologies which constitutes both waste degradation and final disposal, rather than simply long-term waste storage. In a land treatment system, wastes are applied and mixed into the soil using conventional farm equipment. When properly operated, waste constituents undergo biological, chemical, and physical processes that minimize their potential impact on the environment. By these processes, the organic fraction of the waste is degraded or transformed and the inorganic constituents are immobilized.

Disposal at the well site is often restricted by state regulatory requirements, limited land area for disposing the wastes, excessive waste constituent concentrations, or the landowner requesting the waste be hauled off-site. When the waste cannot be disposed at the well site, it must be taken to a commercial disposal facility. Commercial land treatment facilities provide a viable waste disposal option whereby oilfield wastes are treated and disposed in a controlled system. The treatment zone, unsaturated zone, and ground water are monitored, usually on a quarterly basis, to ensure that waste constituents are being treated and adequately contained. This information is also used for developing management recommendations for the facility.

- 9) **Field, M. M., and W. G. Smith. Design Considerations For Landfarming Non-Hazardous Oilfield Waste Drilling Fluids, pres. at Okla. Univ., et. al., Drilling Muds National Conference, Norman, Okla., pp. 395-409, May 29-30, 1986.**

ABSTRACT:

Adverse environmental impacts have occurred in Louisiana and other areas of the nation due to clandestine or improper disposal of many types of liquid and solid wastes, including oilfield wastes. The Louisiana Department of Natural Resources, Office of Conservation, has recognized the need for handling waste drilling fluids in an environmentally sound manner. Accordingly, regulatory amendments have been promulgated in 1984-86 governing the off-site storage, treatment and disposal of waste non-hazardous oilfield drilling fluids by commercial facilities. This set of regulations recognizes that the treatment of waste drilling fluids in a land treatment (landfarm) system is the preferred methodology for handling the fluids. Research conducted on various types of waste drilling muds indicated that the majority

of these wastes, when segregated at the production site from hazardous/toxic wastes, are amenable to biological degradation, and can serve as soil amendments in certain soil types. This paper discusses appropriate guidelines for the landfarming of waste oilfield drilling muds. Regulatory guidelines for oilfield waste treatment and disposal facilities consists of three main areas: location standards, design considerations, and operational considerations. Location standards which are discussed include: location of facilities with respect to flood zones, soil characteristics, and locations of aquifers. Design requirements are related to the prevention of the movement of non-hazardous oilfield waste or waste constituents into underground drinking water sources, and also include levee construction, spill containment, and security. Operational requirements include financial assurance, manifesting of wastes, testing of incoming wastes and the soil matrix, ground water monitoring, and record keeping and reporting. The applicability of the standards to upgrading existing facilities is discussed.

- 10) **Whitfill, D. L., and P. A. Boyd. Soil Farming of Oil Mud Drill Cuttings, SPE/IADC 16099, pres. at SPE/IADC Drilling Conference, New Orleans, La., pp. 429-438, March 15-18, 1987.**

ABSTRACT:

In 1980, Conoco recognized the need for proper disposal of oil mud cuttings and has conducted both controlled "pilot-scale" soil farm studies and full scale field studies. Both the pilot scale and full scale studies show rapid reduction of hydrocarbons for both diesel oil and mineral oil base muds--up to 90 percent oil reduction within one year.

In addition to demonstrating the rapid reduction of oil, these studies also show the immobility of both hydrocarbons and heavy metals in the soil. The comparison of concentrations in the upper 1 foot of soil with those below 1 foot shows no increase in concentration of either hydrocarbons or metals by downward leaching.

These tests also show no preferential leaching of hydrocarbon species, with the relative fraction of both paraffins and aromatics decreasing with time and depth of sampling. Other studies of land farming processes have established a 5 weight percent oil-in-soil treatment level as being environmentally safe. In summary, the soil farming of oil mud cuttings and drilling wastes is a viable and environmentally sound means of disposal.

- 11) **Loehr, R. C., J. R. Ryan and J. E. Rucker. Land Treatment Is a Viable Technology For Reducing Petroleum-Waste Toxicity and Migration Potential, Oil and Gas Journal, pp. 40-43, Nov. 2, 1987.**

ABSTRACT:

Land treatment is a managed technology that involves the controlled application of a waste on the soil surface and the incorporation of the waste into the upper soil. It is not the indiscriminate dumping of the waste on land, and differs significantly from landfilling, waste piles, and surface impoundments. These methods store wastes in man-made or natural excavations and use a combination of liners and leachate collection systems to control the migration of the waste or resultant by-products. Land treatment relies on the dynamic physical, chemical, and biological processes occurring in the soil. As a result, the constituents in the applied wastes are degraded, immobilized, or transformed to environmentally acceptable components.

- 12) **Ghassemi, M. Innovative In Situ Treatment Technologies For Cleanup of Contaminated Sites, Journal of Hazardous Materials, v.17, pp. 189-206, 1988.**

ABSTRACT:

In situ treatment of waste and soil at contaminated sites offers an alternative to the traditional approach to site remediation involving excavation and redispersion or on-site isolation. The in situ "Detoxifier" is an innovative technology/equipment potentially capable of implementing a range of in situ treatment methods (e.g., air/steam stripping, neutralization, solidification/stabilization, oxidation, etc.). It is an adaptation of the drilling technology providing capabilities for in situ delivery of treatment agents in dry, liquid, slurry, or gaseous form to the soil and thorough mixing and homogenization of a vertical column of soil. The recent field demonstration of the mobile system in a full-scale site remediation application at a site

in Southern California was documented. the soil at the site was contaminated with hydrocarbons from leaking underground fuel storage tanks. Steam and hot air were used to strip hydrocarbons from the soil; the off gas was processed in a treatment train and recycled to the soil. By adjusting treatment conditions, the total petroleum hydrocarbons concentration in the soil could be reduced from an initial level of 5,000 ppm or higher to less than 100 ppm. Based on field demonstration results, the equipment vendor is developing designs for a more powerful and compact Detoxifier with enhanced off gas treatment capabilities.

- 13) **Anonymous. USA Report, The Oilman, p. 44, Nov. 1986.**

ABSTRACT:

A method is presented that reduces leaching of toxic materials from disposal pits. Leaching of toxic material from disposal pits is not permitted under current environmental regulations. This method incorporates an impermeable clay formulation that is used as a pit liner. The material is also impermeable to gasoline and oil. this method would be applicable in those states that still permit disposal pits. This would also be of value in drilling operations for temporary storage pits.

- 14) **Gordon, P. A. Process and Apparatus for Eliminating Oil Field Waste Pits, U.S. 4,774,007, c.9/27/88, f. 2/25/87 (Appl. 18,525). (9 pp; 14 claims).**

ABSTRACT:

A process and an apparatus for eliminating oil field waste pits are described. The apparatus has a housing mountable on a trailer for conducting the process in situ. A pump withdraws substantially all hydrocarbon-contaminated matter from the oil waste pit and delivers it into a lower chamber formed in the housing, wherein the hydrocarbon-contaminated matter is separated from the heavy solid particles and heavy salt water. The hydrocarbon-containing mixture, after being separated in the lower housing, is delivered into the upper chamber formed in the housing and heated to facilitate separation by gravity of hydrocarbons, water, and fine particles into various layers for subsequent withdrawal from the housing. The process of withdrawal of the hydrocarbon-contaminated mixture continues until hydrocarbon content of the oil waste pit is reduced to such a degree that the waste pit becomes substantially hydrocarbon-free and is environmentally safe.

- 15) **Anonymous. OGJ Newsletter, March 6, 1989.**

ABSTRACT:

Texaco may have an economic solution to disposal of some oil field waste. It produced fuel grade synthesis gas from 2,500 gal. of tank bottoms sludge using its coal gasification process at its Montebello, Calif., research lab. The sludge was gasified with a coal slurry under high pressures and temperatures to yield a clean, medium BTU gas with no hazardous byproduct. In California, tank bottoms sludge must be transported via truck from oil fields to approved hazardous waste disposal sites.

- 16) **Project proposal submitted to NIPER.**

SUBJECT:

Well plugging gel for bypassing highly permeable zones.

ABSTRACT:

A gel is being considered for evaluation that can be used to plug wells. Claims indicate that the gel can later be broken down when desired to re-access the well.

- 17) **Canter, L.W. Problems of Abandoned Wells, pres. at. Univ. Okla., et. al., First National Conference on Abandoned Wells: Problems and Solutions, pp. 1-15, May 30-31, 1984.**

ABSTRACT:

Abandoned oil and gas wells can serve as conduits for the transport of pollutants from saline or otherwise-polluted geological zones to fresh water aquifers. Abandoned wells are of particular concern in the implementation of the Underground Injection Control Program. It is conservatively estimated that

approximately 2.0 million oil and gas wells have been abandoned in the United States since the first well was drilled 125 years ago. Numerous isolated examples of the influence of abandoned oil and gas wells in causing ground water pollution can be cited even though no nationwide, systematic study has been conducted to ascertain the nature and extent of ground water quality problems resulting from abandoned wells. Mitigation of problems from abandoned wells can be achieved via proper plugging practice. Systematic research is needed on ground water pollution problems, hydrogeological and pollutant transport factors influencing the pollution potential of abandoned wells, a pollution potential prioritization methodology, and the effectiveness of current plugging practices.

18) Smith, M. D. Feasibility study of the Effectiveness of Drilling Mud as a Plugging Agent in Abandoned Wells, EPA(RSKERL) p.84, 1989.

ABSTRACT:

Current methods of plugging dry and abandoned wells in many states call for placing cement plugs through selected zones and drilling mud through the intervening intervals. In some states only drilling mud is used as a plugging agent and this method has been used for many years. In the vicinity of injection wells used for disposal or for secondary recovery of petroleum, numerous plugged and abandoned wells may exist. The environmental concern is the potential for the injected fluids to migrate up through these abandoned boreholes plugged with drilling mud, and enter fresh water aquifers.

The objectives of this research project are to: determine if drilling mud is an adequate plugging material when abandoning wells; develop techniques and associated instrumentation to enter previously plugged wells; and to determine the efficiency of the plugging material used.

To accomplish these objectives, a 2000 foot well will be drilled on the property of Oklahoma State University at the Petroleum Outdoor Laboratory. The well, with extensive surface and subsurface monitoring equipment has a simulated reservoir at the surface and can represent various geological conditions. Simulation of field conditions can be made with respect to depth, fluid pressures, injection fluids and, pressure and plugging agent properties.

STATUS:

The 2000' well has been drilled and cased. Surface testing equipment is being constructed.

19) Zenon Environmental, Inc. Membrane Processing of Oil Field Produced Water for Enhanced Oil Recovery (EOR) Steam Generation, 2 vols., 376 p., 1987.

ABSTRACT:

Cross flow ultrafiltration systems may provide a valuable alternative to conventional treatment of oil field produced water emulsions. All membranes rejected nearly all suspended oil and solids. A thin film was chosen for further work due to its stable flux. An economic assessment showed that the treatment cost, using ultrafiltration, is comparable with conventional treatment at flux rates over 3 m³/m²/d. Significant improvements can be made by reducing the cost of membranes modules and by increasing flux rates obtained.

20) Wilson, E. M. EPA Develops Injection Well Pressure Test, Part 1 - Background Information and Test Well Setup, Petroleum Engineer International, v.60,n.3, pp. 34-39, March 1988.

ABSTRACT:

In the Ada pressure test, the fluid level in a well is measured to determine the height of the water column above the perforations, the pressure required to depress this column of water to the top of the perforations is calculated. Nitrogen then is added to the annulus until the pressure no longer increases. If the test pressure stabilizes at or very close to the calculated pressure and remains constant for 30 minutes after closing the valve to the nitrogen source, there are no leaks in the casing above the perforations and mechanical integrity is demonstrated. The same test may be used inside the tubing and packer. The method was used to test 13 wells in Osage County in 1986. All were witnessed by EPA inspectors and the results were conclusive. Five of the wells passed and eight failed.

Three case histories covering the basic spectrum of conditions that will be encountered on wells with this type of test are presented in the second and concluding part of this article as operational examples of the pressure test. From these examples, the Ada pressure test proves to be a practical, economical, and reliable test for establishing the mechanical integrity of a well. In addition, the conditions for application of the test assures the protection of the underground source of drinking water as mandated by federal regulations.

21) **Kamath, K. I., G. D. Harmon and R. A. Anzzolln. Significance of Regulatory Constraints on the Operation of Packerless Waste Injection Wells, Journal of Petroleum Technology, pp. 1501-1505, November 1988.**

ABSTRACT:

Federal regulations for groundwater protection require all hazardous-waste disposal wells to be constructed so that casing leaks can be reliably monitored. Wells constructed with static-fluid seals instead of packers are incapable of meeting this requirement and are therefore not in compliance with the regulations.

22) **Cole, R. C. and K. Lindstrom. Well Integrity Maintenance Using Pumpable Sealants, pres. at the International Symposium on Subsurface Injection of Oilfield Brines, New Orleans, La., May 6-7, 1987.**

ABSTRACT:

Integrity of Class II disposal wells can be restored and maintained by applications of a variety of pumpable sealants.

In this paper many of the diverse causes for failure of Class II disposal wells to pass state and federal integrity tests are discussed, as well as methods for identifying these causes. Experience with many well histories has shown that, because of their diverse nature, not all of these problems can be remedied with a single product or technique. Therefore, thorough problem diagnosis is emphasized in addition to a description of the application of several sealant systems to overcome the problems.

Considerations are given to overall well conditions, age of the casing string, magnitude of the failure, associated well temperature and hydraulic pressures, and the nature of the fluids against which a seal is required. Portland cement slurries (used alone, or in conjunction with secondary sealants), true solution type sealants capable of entering the formation matrix, microannuli, or pinholes in pipe are discussed.

23) **Collins, A. G., and M. B. Kayser. Interaction, Compatibilities and Long-Term Environmental Fate of Deep-Well-Injected EOR Fluids and/or Waste Fluids With Reservoir Fluids and Rocks - State-of-the-Art, NIPER-70, 103 pp., 1986.**

SUBJECT:

Injection wells.

ABSTRACT:

A state-of-the-art paper with respect to:

Interactions and compatibilities with reservoir rocks and fluids
Their long-term environmental fate.

The following recommendations are noted in the report:

It was recommended that abiotic and biodegradation transformations, transport, and ultimate fate of EOR chemicals and their by-products in soils and waters be determined for:

Mobility control agents
Cosurfactants
Surfactants
Alkaline flooding agents
PREFLUSH agents
Thermal enhancers

Biocides
Chelating agents
Oxygen scavengers
Solid wastes from steam floods
Potentially dangerous chemicals used in any EOR operation

It was recommended that monitoring methods be devised that can be used in the event of a spill of any EOR chemical.

It was recommended that better methods of proving the integrity of injection wells, production wells, storage tanks, treating facilities, etc. be devised and tested.

It also was recommended that fail safe methods be used to prove that injected solutions are not entering geologic zones other than those for which the EOR operation was designed.

Further, it was recommended that research be conducted to develop standard procedures to provide remedial action in the event of a spill that contaminates land, water, or air.

24) **Collins, G. and H. B. Carroll, Jr. Subsurface Injection of Fluids for the Recovery of Petroleum, pres. at the International Symposium on Subsurface Injection of Oilfield Brines, New Orleans, La., pp.79-131, May 4-6, 1987.**

ABSTRACT:

This report addresses the major methods used to recover petroleum which are classified as (1) primary, (2) secondary, (3) tertiary or enhanced oil recovery (EOR). Further, EOR methods which include miscible, thermal, and chemical are described. Subsurface injection of fluids is used in secondary and tertiary petroleum recovery operations.

The report notes that one of the most important criteria relevant to an injection operation is adequate geologic and engineering characterization of the subsurface reservoir. Reservoir screenings and detailed characterizations of reservoirs are made by use of appropriate computer models.

Laboratory studies are conducted using core samples taken from the target injection zone in conjunction with appropriate dynamic flowthrough core apparatus, whereby porosity, permeability, ion exchange, clay sensitivities, rock wettability, miscibility, etc. are determined. The laboratory data and the characterization data are used in an appropriate computer model to predict the probable hydrologic transport and flow of the injected fluids and the targeted petroleum. If these studies indicate a high probability of success for economic petroleum recovery, the next step is a pilot field test. If the pilot test indicates that an economic amount of petroleum can be recovered, then a full-scale field operation is designed and properly sited, wells are drilled, injection and production equipment is installed, and the petroleum recovery operation begins.

Important operations may include reservoir preflush for the removal of the connate brine; injection fluid treatment to mitigate clay sensitivities or to prevent corrosion and incompatible reactions. The waters used in injection operations consist of formation water, fresh water, or seawater, and consideration must be given to fluid-fluid interactions and fluid-rock interactions.

Micellar-polymer, polymer, alkaline, carbon dioxide, steam, in situ combustion, miscible hydrocarbon, inert gas, and microbial EOR processes are briefly described. The types and amounts of some of the injected chemicals also are addressed.

25) **Anonymous. The Oilman, pp. 44-47, Nov. 1986.**

SUBJECT:

Communication among formations/aquifers due to casing leaks.

ABSTRACT:

A new completion/workover fluid is described that forms a protective coating on metal surfaces

and is stable up to 450° F. Environmental communication among zones in a reservoir can be detrimental in a number of ways. If the leak occurs into a freshwater aquifer consequences can be serious. This method would be used during well completion or workovers. This method would not only possibly benefit the environment, but could possibly result in economic savings to the operator if corrosion of casing is reduced.

26) Hill, E. C., J. L. Shennan, and R. J. Watkinson. **Microbial Problems in the Offshore Oil Industry**, pres. at the International Conference organized by the Institute of Petroleum Microbiology Committee, Aberdeen, pp. 165-173, April 1986.

SUBJECT:

The effect of oil produce waste streams in a marine environment.

ABSTRACT:

Experiments following oxygen consumption in simple Closed Bottle experiments using production water diluted with seawater containing a mixed marine microbial population demonstrated a rapid oxygen consumption. Such results indicated the components of production water to be very readily biodegradable and the stoichiometry of the oxygen uptake for carbon added indicated other oxidation processes to be taking place.

Batch growth experiments, using production water as sole carbon and nutrient source, inoculated with mixed marine communities isolated from the North Sea, demonstrated rapid and extensive microbial growth. Gas chromatograms of the extracted dissolved hydrocarbons from samples of the culture broths taken at intervals demonstrated the removal of many of the hydrocarbon and phenolic compounds from the complex mixture.

New sample preparation and ion chromatography methods for the detection of fatty acids in seawater also allowed the monitoring of the rapid disappearance of fatty acid components which were removed to the limits of detection.

In conclusion it has been demonstrated that the organic material discharged in production waters of offshore platforms provides a readily biodegradable carbon substrate for the indigenous microbial flora. These micro-organisms have the potential to rapidly mineralize this material to carbon dioxide and water as a result of their own proliferation.

27) Jackson, G. E. **Oily Wastewater Treatment in the Production of Crude Oil**, pres. at a Symposium Organized by the North West Region of the Industrial Division, Univ. of Manchester, pp.92-107, March 22-23, 1983.

ABSTRACT:

The optimum process or combination of processes for a particular oily wastewater depends on a number of factors, i.e. oil droplet size distribution, oil concentration, gravity of oil, level of suspended solids, presence of surfactants, etc. The optimum process will produce the required effluent water quality at the lowest capital operating and maintenance cost. Oil removal processes are as follows:

- 1) Gravity separation
- 2) Air flotation
- 3) Dissolved air flotation (DAF)
- 4) Filtration System

The processes listed above for treating oily wastewater can all be enhanced by the addition of an appropriate chemical. Selection of a chemical treatment programme and optimization of the process can be achieved by use of laboratory tests followed by full scale plant trials. These should be closely supervised and monitored.

The data presented on polyelectrolytes illustrates the importance of charge density as one parameter which determines their efficiency in various water treatment processes.

- 28) **Leuterman, A. J. J., F. V. Jones and J. E. Candler. Drilling Fluids and Reserve Pit Toxicity, Journal of Petroleum Technology, pp.1441-1444, November 1988.**

ABSTRACT:

Drilling fluids are now classified as exempt under the Resource Conservation and Recovery Act (RCRA) hazardous waste laws. Since 1986, however, the U.S. Environmental Protection Agency (EPA) has been studying reserve pit contents to determine whether oilfield wastes should continue under this exemption. Concerns regarding reserve pit contents and disposal practices have resulted in state and local governmental regulations that limit traditional methods of construction, closure, and disposal of reserve pit sludge and water. A great deal of attention and study has been focused on drilling fluids that eventually reside in reserve pits.

In-house studies show that waste from water-based drilling fluids plays a limited role (if any) in possible hazards associated with reserve pits. Reserve pit water samples and pit sludge were analyzed and collated. Analyses show that water-soluble heavy metals (Cr, Pb, Zn, and Mn) in reserve pits are generally undetectable or, if found in the total analysis, are usually bound to clays or organics too tightly to exceed the limitations as determined by the EPA toxicity leachate test. Our experience is that most contamination associated with reserve pits involves high salt content from produced waters and/or salt formations, lead contamination from pipe dope, or poorly designed pits, which could allow washouts into surface waters for seepage into ground water sources. Our analyses show that reserve pits associated with water-based drilling fluid operations should not be classified as hazardous; however, careful attention should be paid to reserve pit construction and closure to help avoid any adverse environmental impact.

- 29) **Breteler, R.J., A. G. Requejo and J. M. Neff. Acute Toxicity and Hydrocarbon Composition of a Water-Based Drilling Mud Containing Diesel Fuel or Mineral Oil Additives, Chemical and Biological Characterization of Sludges, Sediments, Dredge Spoils, and Drilling Muds, ASTM STP 976, Philadelphia, pp.375-390, 1988.**

SUBJECT:

Toxicity of drilling mud.

ABSTRACT:

A series of static and flow-through toxicity tests was conducted to determine the toxicity of drilling mud that contained three classes of hydrocarbon additives - low-sulfur diesel fuel, high-sulfur diesel fuel, or a commercial mineral oil additive - to four species of marine invertebrates. The hydrocarbon additives were chemically characterized by computerized gas chromatography/mass spectrometry. The base mud was a laboratory-formulated freshwater lignosulfonate mud. Acute toxicity tests were performed with mysids (*Mysidopsis bahia*) by using the suspended particulate phase (SPP) of a 1:9 solution of drilling mud with seawater. Ten-day solid phase (SP) toxicity tests were conducted with sand worms (*Nereis virens*), grass shrimp (*Palaemonetes pugio*), and soft-shell clams (*Mya arenaria*) by using mud solids that settled to the bottom of the mixing container during a 1-h settling period. Exposure concentrations of total organic carbon (TOC) were confirmed analytically. Base mud without additives was practically nontoxic. Drilling mud that contained 5% mineral oil was less toxic than mud containing 5% of either low- or high-sulfur diesel fuel additive, with LC₅₀ values of 3090, 451, and 276 mg/L, respectively. Drilling mud solids containing mineral oil were not acutely toxic to the test organisms, but lethality was observed when animals were exposed to the mud solids that contained 5% diesel fuel.

- 30) **Borchardt, J. K. and D. L. Brown. A Unique Enhanced Oil Recovery Injection Fluid, pres. at Symposium on the Chemistry of Enhanced Oil Recovery, Philadelphia, pp.142-1146, August 26-31, 1984.**

SUBJECT:

Use of polyacrylamides as mobility control agents.

ABSTRACT:

In secondary and enhanced oil recovery, the rate of oil production is directly related to the rate of fluid injection. An efficient displacement mechanism and high volumetric sweep efficiency are insufficient for economic success if an adequate rate of fluid injection and oil production cannot be maintained. Both

total fluid injection rate and the rate of fluid injection at each injection well are integral parts of EOR project design. If the designed injection rates cannot be maintained at one or more fluid injection wells, the pattern of fluid movement through the reservoir becomes distorted and some of the oil may no longer flow toward the nearest production well. Diversion to more distant production wells reduces the rate of oil production and can decrease the oil recovery efficiency. Also, diversion of oil out of the limited acreage of a pilot flood can seriously affect the significance of the production data.

Use of polyacrylamides as mobility control agents in enhanced oil recovery has become well-known. Advantages of acrylamide-containing polymers are their excellent viscosity properties at small concentrations in very low salinity solutions and their relatively low cost. Disadvantages include the effect of small monovalent and divalent metal ion concentrations present in the mixing water on solution viscosity and irreversible shear degradation which can occur during mixing, pumping, injection through the perforation and in the high radial flow velocity region within a 3-10 ft. radius of the injection wellbore.

31) **Matthews, J. E. and L. Hastings. Evaluation of Toxicity Test Procedure for Screening Treatability Potential of Waste in Soil, Toxicity Assessment: An International Quarterly, v.2, pp 265-281, 1987.**

SUBJECT:

A method to determine loading rates and detoxification potential for hazardous industrial waste in soil.

ABSTRACT:

A toxicity procedure has been developed and proposed for use in establishing acceptable initial loading rates and detoxification potentials for hazardous industrial waste when combined with soil. The procedure involves conducting toxicity screening and toxicity reduction experiments using selected waste-soil combinations. These experiments employ a bacterial bioluminescence assay (Microtox TM) to determine acute toxicity of organic contaminants contained in the water soluble fraction (WSF) of waste-soil mixtures. Toxicity screening test results are used to establish a range of loading rates acceptable for use in subsequent waste-soil treatability studies. Toxicity reduction experimental results are used to determine soil detoxification potentials over time for soluble toxic organics contained in the waste-soil loading combination selected. A major factor in determining acceptability of any test procedure is whether or not different investigators can achieve reproducible and comparable results. This paper describes the proposed procedure and reports results from toxicity experiments conducted concurrently by two laboratories using aliquots from the same soil and waste samples. Comparability of creosote aliquots were highly comparable between the two laboratories, while results results for highly variable creosote wood preserving waste (WPC) aliquots were much less comparable. Toxicity reduction experimental results for the WPC waste also indicated significant variation between laboratories for initial (Day 0) samples; however, the same patterns of detoxification over time were observed by each laboratory with toxicity results at the end of the experimental period (Day 42) being similar.

32) **Wilcox, T. C. and J. P. Langlinais. Waste Injection: Testing for Mechanical Integrity, Water Resources Bulletin, v.20,n.1, February 1984.**

SUBJECT:

Methods to correct for variations in pressure due to temperature fluctuations in an injection well.

ABSTRACT:

The recently enacted Safe Drinking Water Act charges the Environmental Protection Agency with developing regulations to protect fresh ground water from contamination by waste injection operations. Ground water containing 10,000 ppm or less dissolved solids is defined by EPA to be fresh water. These regulations constitute the Underground Injection Control program, for which states can obtain primacy for enforcement, or the regulations would be enforced by the EPA itself. Of particular interest to operators is the requirement that injection wells be equipped with tubing and packer, and that mechanical integrity (i.e., no leaks in casing, tubing, or packer) be maintained (see Figure 1).

A generally accepted method to show mechanical integrity is to monitor hydraulic pressure applied to the closed fluid filled annular volume (i.e., the space between the casing and tubing of an

injection well). If a completely stabilized temperature profile throughout the length of the well and a constant injection pressure could be maintained, then a change in annulus pressure would indicate loss of mechanical integrity. However, injection pressure and waste stream temperature changes are very common, and these changes are reflected in annular pressure changes.

This work is an effort to represent mathematically all parameters that affect the casing, tubing, and annular fluid dimensions, and then calculate the resulting change in the applied annular pressure. These calculations were done with the use of a computer, using an incremental depth step approach.

33) **Monick, B. and A. Blake. Process and Composition for Removing Contaminants From Wastewater, U.S. Patent 4,765,908, Appl. 16,503, Aug. 23, 1988.**

SUBJECT:

Process to remove a number of contaminants from wastewater in the form of a nonleachable sludge.

ABSTRACT:

A treatment composition and method is provided for removing a plurality of contaminants from a wastewater system in the form of a nonleachable sludge. The treatment composition comprises and alkali or alkaline carbonate; activated montmorillonite; a catalyst, such as zirconium and polyelectrolyte; one or more flocculants, such as a metal salt and calcium oxide, lime, or calcium hydroxide; and bentonite. Additionally, the treatment composition may contain soda ash, lignite, and activated carbon. The treatment composition is introduced and mixed with the wastewater, which is then filtered to produce a sludge containing the contaminants in a nonleachable form.

34) **Terry, E. G. B. and L. K. Seedall, Treatment of Oil Field Wastes, U.S. Patent 4,751, 887, Appl. 96,894, June 21, 1988.**

SUBJECT:

Treatment of oil field wastes using a rotating kiln.

ABSTRACT:

A method and apparatus of treating oil field wastes and particularly spent drilling fluids which contain barite and hydrocarbons which includes placing the drilling fluids in to the upper end of a downwardly directed rotating kiln. Fuel and pressurized air are inserted into a furnace connected to the upper end of the kiln for supplying a fire to the drilling fluids in the kiln for igniting and burning the hydrocarbons in the drilling fluids as fuel until the drilling fluid is dry. Entrained particulates in the gas stream leaving the kiln are separated in a cyclone separator. The gases leaving the cyclone separator are passed through a secondary combustion unit to assure complete combustion of pyrolyzed carbonaceous residuals in the gas stream. The gases are then cooled in a heat exchanger and sent to a hydrosonic scrubber which removes the remaining particulates as well as oxides of sulfur. The gases are transported to a vent stack by use of a suction blower which produces the gas flow in the gas handling separation system. The liquids used in the hydrosonic scrubber are processed through a filter system to remove any particulates entrained therein. The solids dropping from the lower end of the kiln are environmentally stable and are then usable as landfill or road bed fill materials.

35) **Beer, G. L. and H. L. Ying. Method and System For Treating Drill Cutting Slurries and the Like, U.S. Patent 4,747, 961, Appl. 944,644, May 31, 1988.**

ALSO: European Patent No. 0,276,546, Appl. 87309658.0, Filed: 2-11-87

SUBJECT:

A method to treat drill cutting slurries and similar mixtures for environmentally safe disposal.

ABSTRACT:

Drill cuttings, and similar slurries or mixtures oily solid particles, are treated by a dryer apparatus which vaporizes the liquid and discharges relatively large solid particles for disposal. Vapor and entrained solid fines are conveyed from the dryer to a condenser and then to a rotary drum vacuum filter having a

precoated filter media disposed thereon. The solid fines are filtered by the filter media comprising diatomaceous earth or perlite and the clarified condensed liquid is conveyed to separator means for separating oil, water and any other liquids present. The filter media stripped from the filter and contaminated with entrapped solid fines is conveyed through the dryer means and disposed with the solids particles being discharged from the dryer. The system is particularly adapted for offshore drilling operations and diatomaceous earth may be discharged to the sea after separation from all contaminants such as oil and other liquids in the drilling fluid.

36) **ROY A. K. ELECTRIFYING SOIL CLEANUP, HAZMART WORLD JULY , 1989, pp. 14-15**

ABSTRACT:

This low cost , highly effective method allows decontamination at the waste site without excavation. RF decontamination makes it possible to treat contaminated soil that might not otherwise be treated because of economic constraints or because other low cost treatments are ineffective . With proper design and equipment selection RF decontamination will allow treatment of waste sites between 1000 square feet and one acre that have contaminant penetration up to 20 feet.

37) **Boyd, P. A. Low Toxicity Oil-Based Drilling Fluid, U.S. Patent 4,787,990, Appl. 463,779, Nov. 29, 1988.**

SUBJECT:

Non-fluorescent, low toxicity oil for use in oil-based or water-based drilling fluids.

ABSTRACT:

Disclosed is a low toxicity oil for use in drilling fluids. The oil consists essentially of branched-and cyclic-paraffins having 11 to 17 carbon atoms per molecule and further having a low aromatic content of less than about 1% and a low normal-paraffin content of less than about 5%. The low polynuclear aromatic oil is useful in both oil-based and water-based drilling muds, particularly where low toxicity and lack of water sheen are important such as in offshore drilling environments. The oil also has the advantage of being non-fluorescent so that it does not mask UV fluorescence of formation crudes produced from the drill cuttings in wildcatting operations.

38) **ERT and Remediation Technologies Inc. Land Treatability of Appendix VIII Constituents Present in Petroleum Refinery Wastes: Laboratory and Modeling Studies, API Publication No. 4455, April 1987.**

SUBJECT:

Land treatability for refinery wastes.

ABSTRACT:

The degradation, immobilization, and transformation of organic constituents present in refinery wastes which are land treated was evaluated through a series of laboratory and modeling studies. These studies were based on previous literature reviews concerning (a) the range of site, waste and operating conditions found at refinery land treatment facilities (API, 1983), and (b) the degradation and immobilization of refinery waste constituents (API, 1984).

The studies clearly show that within the range of site, waste and operating conditions expected to be found at most refinery land treatment facilities, the applied constituents can be degraded, transformed, and immobilized within the treatment zone of the facility.

This study has shown that refinery wastes constituents have different rates of degradation and mobility in a land treatment system. Although a variety of site and operational factors can affect these rates, it has been shown that the soil is an extremely flexible and effective treatment medium.

The results of this study significantly expand the data base available on the land treatability of refinery wastes. The data base clearly demonstrates that land treatment is a viable technology for treating petroleum refinery wastes under controlled environmental conditions. With proper design and care, the

applied waste constituents can be effectively managed within the soil treatment zone thus minimizing the potential for uncontrolled release to the environment.

39) **Matthews, J. Review and Evaluation of Current Design and Management Practices for Land Treatment Units Receiving Petroleum Wastes, EPA/600/J-86/264, Hazardous Waste & Hazardous Materials, v.3, n.3, pp.261-280, 1986.**

SUBJECT:

Practices at petroleum waste land treatment facilities in the U.S. Waste degradation rates and application frequency were observed.

ABSTRACT:

This paper describes the land treatment practices used by petroleum waste land treatment facilities in the U.S. Information obtained for 13 full-scale land treatment facilities included types of waste land treated, characterization of land treated wastes, waste application rates (loading rates), waste application frequencies, and management practices used at the treatment units.

Engineering design matrices which illustrate the relationships among waste application rate, application frequency, and waste degradation rate, and the effect of these parameters on stabilized concentrations during the active life of a unit were developed. Waste degradation half-life and waste application frequency were observed to have greater influence in determining the stabilized weight percentage of oil in the treatment soil than waste application rate. A three-dimensional graph was developed as an example of how design matrices can be used as engineering/management aids for petroleum land treatment site design and operation.

40) **Hanson, P. M. and F. V. Jones. Mud Disposal, An Industry Perspective, Drilling, pp. 16-21, May 1986.**

SUBJECT:

Basic problems of mud disposal created by changes in environmental regulations.

ABSTRACT:

Present legislative trends indicate that environmental regulations, and the costs associated with compliance, will become a more significant portion of total well costs in the future... It is evident that industry must continue to search for methods of land disposal which are both environmentally acceptable to state regulatory agencies and economically favorable to drilling operations.

Offshore operators have two options: they can discharge into the surrounding water or transport all waste mud and cuttings back to shore for land disposal. The first option requires that operators be restricted to a select group of water based muds and additives which meet stringent limits... The cost of compliance in this case is somewhat intangible because it is difficult to assess the "price" of mud type limitations in terms of drilling problems which might have been avoided or delays which might not have occurred. Costs which are more easily quantified are expenses related to product substitution and development of "environmentally safe" products as well as the cost of bioassays needed to demonstrate the acceptability of these products. Shipping drilling mud and cuttings to shore for disposal imposes both economic and operational hardships on operators. The cost of this method can be as much as 22 percent of the total well cost.

41) **Drlessen, P. K. Drilling Fluids: Thy Name Is Mudd, Petroleum Management, pp. 56-61, August/ September 1988.**

SUBJECT:

A discussion of the toxicity of drilling muds relative to other marine contaminants.

ABSTRACT:

...if drilling fluids block the ability of shellfish to find substrates, how does one explain the presence of literally millions of healthy, fast growing mussels, barnacles and rock scallops under every California platform? In fact, state and federal health agencies have consistently found that mussels

harvested from California platforms contain less chemical and trace metal pollution than do mussels taken from Bodega Bay, the Golden State's cleanest bay.

The reason is simple. Discharges from California OCS platforms are actually quite small and typically occur 3-8 miles from shore in waters 150-900 feet deep, where strong currents mix and disperse any pollutants. The state's major pollution sources are actually rivers and wastewater treatment plants, which empty into near shore waters that are comparatively shallow, more biologically productive, important as fish and shellfish breeding grounds, and frequently used by swimmers.

- 42) **Stearns, M. O. and J. A. Gill. Pollution-Free Well Cuttings Disposal Apparatus, U.S. Patent 3,901,254, Oct.5, 1973.**

SUBJECT:

Apparatus for removing oil from drill cuttings at an offshore platform.

ABSTRACT:

Apparatus for removing oil from drill cuttings at an offshore drilling location above the surface of a body of water comprising in combination a platform; a partially submerged down pipe extending both above the surface of the water and below the surface of the water; means on said platform for shaking oily mud from said cuttings by vibratory screening action; means on said platform for discharging said shaken cuttings onto cuttings washer means; means on said platform and associated with said cuttings washer means for spraying said cuttings with a wash liquid; pump means on said platform for collecting said wash liquid subsequent to its contact with said cuttings and for pumping it to desilting means located on said platform; return flow means for recirculating said desilted wash liquid to said cuttings washer means; means for conveying washed cuttings from said platform to a point within said down pipe and below the surface of said water; pump means for pumping oil dislodged from said cuttings in said down pipe and present within said down pipe adjacent the surface level of said water to oil-water separating means; means for receiving oil discharged from said oil-water separating means.

- 43) **McNally, R. Tougher Rules Challenge Future For Injection Wells, Petroleum Engineer International, pp. 28-30, July 1987.**

SUBJECT:

Impact of new regulations regarding Class II injection wells.

ABSTRACT:

According to Charles W. Kreidler, University of Texas, Austin, salinization of soil and the appearance of vegetative-kill areas are major concerns of farmers in the U.S., however, salinization of the soil can be caused by natural and agricultural factors. Mixing of deep-basin salt water with shallow, fresh groundwater results in saline waters with different mineral/chlorine ratios than briny water resulting from evaporation of ground water. This distinction is important as plugging a well can cost as much as \$10,000.

Abandoned wells are possible sources of pollution to water supplies because they allow fluids to migrate upward from the overpressured injection zone into underground sources of drinking water.

Operators are coming under increasing pressure to make sure they know what is happening in their injection wells. And that's not all bad because controlling injection can increase ultimate recovery of oil.

Using chemical and radioactive tracers to identify sources of communication can ultimately save money for the operator.

- 44) **Cheremisnoff, P. N. Water and Wastewater Treatment-Fundamentals and Innovations, Pollution Engineering, pp. 94-99, March 1989.**

SUBJECT:

Methods of wastewater treatment.

ABSTRACT:

METHODS OF WASTEWATER TREATMENT:

- 1) Suspended Solids Removal:
 - a) Microscreening
 - b) Diatomaceous Earth Filtration
 - c) Chemical Clarification
 - d) Chemical Filtration
- 2) Organic Removal
 - a) Activated Carbon Adsorption
 - b) Biological Treatment
 - c) Oxidation
- 3) Inorganic Removal
 - a) Ion Exchange
 - b) Reverse Osmosis
- 4) Nutrient Removal
 - a) Phosphate Removal
- 5) Air Stripping for Pollutant Removal
- 6) Land Treatment
- 7) Innovations
 - a) Freeze-dried Bacteria
 - b) Constructed Wetlands (uses bacteria)
 - c) Grease and Oil Degrading Bacteria (faster than existing bacteria)
 - d) Odor Controlling Instruments

45) **Moseley, H. R. Jr. Summary of API Onshore Drilling Mud and Produced Water Environmental Studies, IACE/SPE 11398, pres. at IADC/SPE 1983 Drilling Conference, New Orleans, La, pp.321-325, Feb. 20-23, 1983.**

SUBJECT:

Toxicity of drilling muds.

ABSTRACT:

The restoration/disposal of drilling mud pits and produced water impoundments is a continuously growing concern to the oil and gas exploration/production industry. To ensure proper restoration of these sites, it is first necessary to determine the environmental effects of drilling muds and produced waters to soils, plants, and surface/ground water. The American Petroleum Institute (API) has sponsored four major studies investigating these impacts to these onshore drilling and production sites.

46) **Dinchak, W. G. A new Composite Liner for Hazardous Waste Impoundments, pres. at The Seventh National Groundwater Quality Symposium, Las Vegas, Nev., pp.480-490, Sept. 26-28, 1984.**

SUBJECT:

Pit liner for wastewater pits.

ABSTRACT:

A composite liner made of a synthetic membrane placed between two 6-in.-(152-mm) compacted lifts of soil-cement has been developed by the Portland Cement Association. Construction feasibility was demonstrated by a test section built in September 1983 near Apalachin, N.Y. Observations show no damage occurred to the membrane. The soil-cement serves as a foundation and protective cover for the membrane. This composite liner is strong, durable, and impermeable with an estimated in-place construction cost of \$1.30/sq ft (\$14/sq m). Conventional highway construction equipment is used.

47) Jones, M. A Preliminary Examination of the Laboratory Sheen Test, Journal of Testing and Evaluation, JTEVA, v.14, n.3, pp. 133-139, May 1986.

SUBJECT:

Test to determine the presence of oil in discharges from offshore drilling platforms.

ABSTRACT:

A proposed test procedure for detecting "free oil" in discharges of drilling fluids and cuttings from offshore oil and gas wells has been evaluated by the Environmental Protection Agency (EPA) and independently. Several preliminary examinations with small numbers of observers were performed, and later expanded by testing with 26 observers. The procedure, including recent modifications, appears to be relatively sensitive but of questionable usefulness as a monitoring tool. Results are highly variable, depending on the type of drilling mud, presence of interfering compounds, and sample size. Other factors (i.e., vibration, angle and type of light, sample age, and sample preparations) may also cause variable results and will need to be more carefully evaluated. The definition of sheen is expanded in the most recently proposed version of the procedure, causing more samples to fail than with previous definitions. It is suggested that the procedure be further evaluated.

48) Somanl, A. H., A. Zaidi and V. Westlake. Produced Water Treatment Technologies for Re-Use or Disposal, pres. at the China-Canada Heavy Oil Technology Symposium Proceedings, Zhuo'Zhuo, China, pp.40.1-40.7, October 26-30, 1987.

SUBJECT:

A discussion of the methods used by Canadian heavy oil producers to clean water used in steam injection for re-use.

ABSTRACT:

In Canada, in-situ heavy oil production requires the injection of 2 to 3 barrels of water in the form of steam for every barrel of oil produced. Produced water varies from 0.5 to 20 barrels per barrel of oil. The Canadian government has begun to limit the use of fresh water for steam injection prompting operators to clean and recycle injection water.

The oil/water mixture is routed through a 3-phase separator and a primary separator to remove gases and to separate produced oil from produced water. The oil-rich stream is subjected to emulsion breakup treatments to produce sales oil. Produced water from the primary separator and from the emulsion treatment process is directed to a skim tank or an induced gas floatation unit for oil removal. Depending on the end use of the produced water, it may be either re-injected into the formation or reused as feedwater in an injection boiler. Further treatment is normally necessary if the water is reused either as utility water or in industrial boiler.

49) Davis, K. E. and M. C. Herring. Laboratory Evaluation of Slurry Wall Materials of Construction to Prevent Contamination of Groundwater From Organic Constituents, pres. at The Seventh National Ground Water Quality Symposium, Las Vegas, Nev., pp. 491-512, Sept. 26-28, 1984.

SUBJECT:

A better method to contain chlorinated hydrocarbons in a wastewater pit.

ABSTRACT:

The installation of earthen liners and slurry wall trenches constructed of soils treated with bentonite and/or bentonite/cement mixtures are frequently used today as a means to retard or control the flow of contaminants from surface impoundments and landfill disposal areas. Although effective in reducing the rate of flow of water and some contaminants, standard bentonite treatment is not always effective in controlling some types of contaminants, such as chlorinated hydrocarbons.

Past handling and disposal of liquid chlorinated hydrocarbon waste in earthen impoundments and a landfill at an existing plant resulted in shallow ground water and soil contamination over a broad area.

Following field investigations, extensive laboratory tests were conducted to investigate the feasibility of confining the plume of contamination through the installation of a slurry trench barrier. Specially designed methods of testing were used during the investigation.

Standard bentonite soil mixtures using up to 6% more bentonite were shown to be ineffective in restricting the flow of the concentrated wastes found in the subsurface strata. However, a 12%/12% bentonite/cement dust soil mixture was shown to completely restrict the flow or movement of the concentrated waste while reducing the flow of ground water and contaminated leachate.

50) **Allen, T.F. and D. G. Austin . Apparatus and Method For Processing Oil Well Brine, US patent 4,804,477. 2/14/89.**

Abstract:

An apparatus and process are described for the controlled concentrating of oil well brine. The apparatus is adapted to be situated at a well site where brine is produced. The apparatus provides a heating means for evaporating water from the brine to cause precipitable salts to precipitate out of solution and to become concentrated with soluble trace elements or minerals, which also are recovered.

51) **Sims, R. C., D. L. Sorensen, W. J. Doucette, and L. L. Hastings. Waste/Soil Treatability Studies for Four Complex Industrial Wastes: Methodologies and Results, EPA/600/6-86/003b, pp.229, October 1986.**

ABSTRACT:

This is Volume 2 of a two-volume report that presents information pertaining to quantitative evaluation of the soil treatment potential resulting from waste-soil interaction studies for four wastes listed under Section 3001 of the Resource Conservation and Recovery Act (RCRA). This volume contains information from bench-scale waste-soil interaction studies. Treatment information, including degradation, transformation, and immobilization data for hazardous constituents are presented. The four wastes included API separator sludge, slop oil emulsion solids, pentachlorophenol wood preserving waste, and creosote wood preserving waste. Chemical analyses and bioassays were used to characterize and quantify treatment potential for soil-waste mixtures.

Specific results and conclusions based on the objectives include:

- (1) Polynuclear aromatic hydrocarbon (PAH) constituents were degraded in all four wastes under conditions of initial waste application to nonacclimated soils as well as when wastes were reapplied to soils. Generally an increase in PAH half-life was correlated with increasing molecular weight or compound size.
- (2) Pentachlorophenol degradation rate in PCP wood preserving waste appeared to be related to the initial loading rate and the loading rate used when the waste was reapplied. Higher initial rates and reapplication rates resulted in higher half-life values.
- (3) All waste-soil mixtures exhibited an initial increase in water soluble fraction (WSF) toxicity followed by a decrease in toxicity with incubation time. The pattern of WSF toxicity with time was considered to be an indication of formation and degradation of toxic intermediates.
- (4) Results for mutagenicity evaluations for detoxification of soil-waste mixtures were dependent upon waste loading rate, waste type, and soil type.
- (5) Partition coefficients determined for PAH and volatile constituents contained in each of the waste evaluated demonstrated highest partitioning of constituents into the waste (oil) phase. Relative concentrations between water and waste (oil) phases for PAH constituents were 1:1000 to 1:100,000, with the higher ratios observed for the petroleum wastes. Relative concentrations among air:water:waste (oil) phases for VOCs were generally 1:100:100,000

Results of the waste-soil treatability studies indicate the importance of loading rate, site (soil) selection, and site management for treatment of hazardous constituents in soil systems.

52) **Anonymous. Drilling Fluids Disposal Issue Concerns Operators and Agencies, Drilling Technology, pp.73-75, July 1982.**

ABSTRACT:

Current methods of drilling mud disposal and their drawbacks (Texas):

- 1) Leave fluids in existing reserve pit to dry out
 - a) it may take along time for the liquid to evaporate
- 2) Trucking the mud to an approved disposal pit
 - a) restricted to freshwater-based mud
- 3) Land farming
 - a) mud must have a low chloride content
- 4) Subsurface disposal
 - a) must submit a request and be reviewed
- 5) Recycling
 - a) mud is trucked to another location and used as spud mud
- 6) Treat mud and discharge as surface drainage
 - a) must have permit

53) **Technical Resources, Inc. Assessment of Environmental Fate and Effects of Discharges From Offshore Oil and Gas Operations. EPA PB86-114964, Aug. 85.**

ABSTRACT:

The overall objectives of this study are to characterize and assess the fate and effects of discharges from offshore oil and gas drilling and production activities. Four specific objectives were outlined by EPA:

- Present overall conclusions on the fate and effects of drilling fluids and cuttings discharged to the marine environment
- Describe types and quantities from offshore drilling and production
- Describe transport phenomena to which discharges will be subjected, including physical, chemical, and biological processes
- Present information on the acute and chronic toxicity of drilling fluids and produced waters on marine organisms.

Section 1 presents background information on offshore drilling and production processes and associated discharges. Section 2 details discharge characteristics and composition, and quantifies discharge volumes; especially for drilling fluids, cuttings and produced water. Section 3 describes the environmental fate of discharges, including physical, chemical, and biological pathways. Toxicity information on drilling muds and produced waters is presented in Section 4. Section 5 presents summaries of field studies of particular interest regarding drilling and production activity. Section 6 presents information on the ecological resource characteristics of marine environments. Section 7 presents the findings and conclusions.

54) **Anonymous. Oil and Gas Industry Exploration and Production Wastes, API Document No. 471-01-09, July 1987.**

ABSTRACT:

The majority of produced waters are injected underground for waste disposal or used as part of an enhanced oil recovery program. A relatively small amount of produced water is discharged to the surface under NPDES or state programs. Produced water accounts for 98% of total industry waste.

Drilling wastes comprise 1.9% of total exploration and production wastes. Drilling waste liquids are generally evaporated, discharged to the surface, transported off site, or injected down the well annulus. Drilling waste solids are generally disposed of by burial or land spreading at the drilling site. Extensive modeling of current drilling waste management practices has shown no significant potential hazard to human health or the environment.

55) Gietz, C.T., R. Montgomery and T. W. Duke. Toxicity of Used Drilling Fluids to Mysids (*Mysidopsis Bahía*). *Environmental Toxicology and Chemistry*, v.5, pp. 813-821, 1986.

ABSTRACT:

Static, acute toxicity tests were conducted with mysids (*Mysidopsis bahia*) and 11 used drilling fluids (also called drilling muds) obtained from active drilling platforms in the Gulf of Mexico in U.S. waters. Each whole mud was tested, along with three phases of each mud: a liquid phase with particulate materials removed, a suspended particulate phase composed of soluble and lighter particulate fractions and a solid phase composed mainly of drill cuttings and rapidly settling particulates. These muds represented seven of the eight generic mud types described by the U.S. Environmental Protection Agency for use on the U.S. outer continental shelf.

56) Jones, P. S. **Water Treatment for Injection and Disposal.**

ABSTRACT:

As oil fields mature, problems associated with treatment of the produced fluids increase, and crude dehydration and subsequent treatment of separated water become more costly processes. Environmental and reservoir constraints set standards for water quality and cost effective treatment to those standards is our goal.

Many factors influence our ability to treat oil field waters for injection and disposal: bacteria, oil and solids contamination as well as equipment limitations are just some of the problems facing us. Cost effective treatment is dependent on correctly identifying the problems and evaluating the possible solutions before deciding on a course of action. Two treatment concepts point the way to this goal: System Evaluation and Point Source treating.

57) Moore, S. D. and R. McNally. **Necessity Inspires Oil Patch Innovators.** *Petrol. Eng. Int.*, v.61, n.1, pp. 19,22,27-28, Jan. 1989 (ISSN. 0164-8322).

ABSTRACT:

Although the real revolution in drilling technology-involving robots and artificial intelligence-still is probably a decade away, innovations currently under way could be regarded as the groundwork for the coming revolution. Current efforts to make drilling more efficient include improved control over cementing, prolonging the life of drill strings and improving pressure predictions.

But much of the industry's success is due to downhole innovations such as measurement-while-drilling systems, steerable downhole motors, and improved drill bits. On the rig, top-drive systems are playing an important role in reducing hole problems and improving safety.

58) Pierce, R. H., D. C. Anne, F. I. Saksa and B. A. Welchert. **Fate of Organic Compounds From Spent Drilling Fluid Discharged into the Sea.** *"Wastes in the Ocean, Energy Wastes in the Ocean"*, v. 4, Wiley, 1985.

ABSTRACT:

Field samples of water and sediment collected from the vicinity of the Texas Flower Garden Banks and from the drilling areas to the north showed a preponderance of biologically derived hydrocarbons in the water column and mostly weathered hydrocarbons resembling crude oil in the surficial sediment throughout the study area. Samples from a small surface discharge from one of the rigs did not show organic compounds to be appreciably different from those reported at the other stations.

Drilling fluid dispersed in seawater resulted in aliphatic compounds that were strongly associated with particles; however, the aromatic compounds were more evenly distributed between the dissolved and particulate fractions.

The petroleum associated with the spent drilling fluid may present a toxicity hazard in bulk discharges even though increased background concentrations were not observed during the small surface discharge.

59) **Skinner, J. L. Drilling Cuttings Treatment. Canadian Patent No. 1,245,844, Filed March 26, 1986.**

ABSTRACT:

In accordance with this invention, there is provided a method and apparatus for removing hydrocarbonaceous oil from drilling cuttings so that the solid drilling cuttings themselves can be disposed of offshore in an environmentally acceptable manner.

Accordingly, it is an object of this invention to provide a new and improved method and apparatus for treating drilling cuttings for disposal purposes.

It is another object of this invention to provide a new and improved method for rendering drilling cuttings environmentally acceptable for subsequent offshore disposal.

60) **Melkrantz, D. H. and G. L. Bourne. Annular Centrifugal Contactors as Rapid Oil-Water Separation Devices. (EG and G Idaho Inc., Idaho Falls (USA)). pres. at Biennial International Oil Spill Conference, San Antonio, Contract AC07-76ED01570. 11 p., (CONF-890202-2), GPO Dep. Order Number DE89005432/JAW, Feb. 13, 1989.**

ABSTRACT:

The results of preliminary tests to apply devices known as annular centrifugal contactors to the rapid separation of oil-water mixtures are presented. Separation efficiencies of oil from water of >99% have been demonstrated on both light and heavy oils. Equilibrium within the separating zone of the contactor is reached within seconds. Dynamic testing in which water to oil flow ratios of 1:5 and 5:1 have been conducted without loss of performance. The laboratory scaled contactors tested have total throughput of 80 c/min. The design and construction of larger devices with total contactors would be compact units capable of allowing rapid recovery from a broad range of hydrocarbon spills on waterways. The efficiency of these contactors is such that water discharged can be returned to the environment. Recovered hydrocarbons may be useful without further refinement.

61) **Freeman, B. D. and J. W. Collins. RCRA Subtitle D Application to Drilling Operations, pres. at the 1989 SPE/IADC Drilling Conference held in New Orleans, La., pp. 451-460, Feb. 28 - Mar. 3, 1989.**

ABSTRACT:

The Environmental Protection Agency (EPA) presented the Regulatory Determination on drilling muds, produced water and associated wastes to Congress on June 30, 1988. One conclusion was regulatory gaps were present in some State oil and gas programs that compromised environmental protection. EPA believes they have authority under Subtitle D to fill these gaps. However, the Subtitle D type waste management guidelines, as being formulated by EPA to regulate mining operations and municipal landfills, are not viable or cost effective when applied to Oil and Gas Industry (OGI) operations. The existing drilling waste management practices used by the OGI in a number of State oil and gas programs though are viable and cost effective to ensure environmental protection. These existing practices as discussed in this paper can be implemented in applicable State programs to fill regulatory gaps.

62) **Jones, M. and G. H. Otto. An Evaluation of EPA Sheen Tests for Drilling Fluid Discharge, pres. at 1987 Oil Spill Conference, pp. 521-528, 1987.**

ABSTRACT:

The U.S. Environmental Protection Agency (EPA) has prohibited the discharge of "Free oil" in offshore drilling discharges and proposed new procedures to detect such oil. A statistically designed series of experiments was performed to evaluate three proposed sheen test procedures: EPA's Gulf of Mexico, Alaska, and cup protocols. Seventy-four independent observers conducted over 6,360 sheen tests. The experiments evaluated the effects of freshwater and saltwater test media, two lighting types, two mud types, and two oil types (diesel and mineral) at five concentrations (including a blank). The cup and Gulf tests had relatively high false positive rates. The Alaska procedure had a lower false positive rate,

but did not detect oil concentrations of 5% reliably under some test conditions. As a result, none of the three procedures used can be considered satisfactory for National Pollutant Discharge Elimination System permit compliance.

- 63) **Marks, R. E. and A. Wojtanowicz. Biodegradation of Oilbased Drilling Muds and Production Pit Sludges, Journal of Energy Resources Technology, v.110, pp.183-188, Sept. 1988.**

ABSTRACT:

Biological degradation of oilbased muds and production pit sludges are examined using batch reactors. Microbial populations from five different sources were screened as to their capability of survival in and degradation of the oils present. Two microorganism cultures, one developed from raw domestic wastewater and the other from a refinery biological treatment system, demonstrated superior acclimation and degradative properties based on substrate utilization and oxygen uptake rates. No toxic or inhibitory properties of the wastes were observed. Biological treatment has the potential to satisfactorily degrade wastes for disposal according to newly established Louisiana requirements, and also as a preconditioning step prior to conventional dewatering techniques.

Elimination of these pits is required by both State and Federal regulatory agencies.

Those pits which are high in oil and grease are often not amenable to cost-effective closure by foregoing methods.

This paper presents the results of the evaluation conducted to determine the potential for biological treatment of oil-based drilling mud/cuttings mixtures and production pit sludges.

- 64) **Hanson, P. M., F. V. Jones, C. M. Moffitt and M. R. Rhea. A Review of Mud and Cuttings Disposal for Offshore and Land Based Operations, pres. at Okla. Univ., et al., Drilling Muds National Conference, Norman, Okla., Proc. pp. 109-122, May 29-30, 1986.**

ABSTRACT:

Waste disposal in oil and gas drilling operations presents a unique challenge encountered in few other industries. Geologists and engineers must locate wells as close to the oil and/or gas resource as possible - not where it is convenient. Costs associated with waste disposal, particularly in this era of environmental awareness, are steadily increasing and are beginning to play a major role in drilling operations. In this paper, we review current methods of mud and cuttings disposal - both for offshore and land-based operations. This includes legislative and regulatory influences, environmental and operational problems, and where applicable, economic impacts.

- 65) **Randolph, T. M. and J. P. Simpson. EPA offshore Effluent Guidelines for Mud and Cuttings Discharges: A Regulatory Impact Model, SPE/IADC 18682, pres. at the 1989 SPE/IADC Drilling Conference held in New Orleans, La., pp. 503-516, Feb. 28 - Mar. 3, 1989.**

ABSTRACT:

Effluent guidelines for discharges of muds and cuttings offshore are under development. The impact of the proposed guidelines is predicted by a model developed as part of the API comments on the 1988 EPA proposal. A preliminary run of this model shows that 25 percent of the drilling wastes will be hauled for onshore disposal, rather than discharged.

- 66) **Canter, L.W. Environmental Management of Drilling Mud Disposal: Historical and Current Concerns, pres. at 2nd Okla. Univ. Drilling Muds National Conference, pp. 1-37, May 28-29, 1987.**

ABSTRACT:

Drilling wastes and produced waters must be appropriately managed in order to minimize negative environmental impacts. This paper provides a review of some historical and current concerns relative to proper environmental management of these wastes and produced waters. The time from 1975 to now is divided into an historical period (1975-1984), a recent period (1985-1986), and a current period (1987). Historical concerns were dominated by marine toxicity studies, with some work on the environmental onshore implications of disposal practices, particularly as related to soil and ground water pollution. Recent concerns have focused on the ground water quality implications of metals and salts mobilized at reserve pits and off-site pits. The current U.S. Environmental Protection Agency (EPA) study on whether or not to classify oil and gas wastes as hazardous has far-reaching environmental and economic implications. Risk assessment, a relatively new concept in environmental management, can provide a useful conceptual framework in decision making for proper environmental management of drilling wastes and produced waters.

- 67) **Forsberg, C. W. Disposal of Hazardous Elemental Wastes, Environmental Science Technology, v.18, n.2, pp.56A-62A, 1984.**

ABSTRACT:

The permanent, safe disposal of toxic elements such as arsenic, cadmium, and lead in hazardous wastes presents technical, political, and economic difficulties. These hazardous elemental wastes are currently disposed of by shallow land burial. Since the wastes are not degradable, they remain toxic forever; hence, shallow land burial grounds remain toxic forever and may require perpetual maintenance.

These problems have generated opposition to shallow land burial and have led to state regulations restricting shallow land burial of such long-lived wastes.

- 68) **Davies, G. E. and J. H. Wensley. Waste Management for a Large-Scale Drilling Project, The Journal of Canadian Petroleum Technology, pp.44-51, March/April 1987.**

ABSTRACT:

In 1985 Shell Canada Limited completed the drilling of 209 wells as part of its Peace River Expansion Project (PREPO). This project generated a combined total of 34,000 m³ of solid and liquid drilling wastes.

Due to the volume of the wastes to be generated and because potassium chloride (KCl) salts would be present in the wastes, a waste management plan was required. The objectives of this plan were:

- Minimize the volume of wastes generated.
- Treat and re-use as much waste liquid in the drilling operation as possible.
- Dispose of all remaining wastes at project completion in an economical and environmentally acceptable manner.

This paper discusses the approach used to develop and implement a waste management plan for a large-scale drilling project. Recommendations are provided to refine this plan for future projects.

- 69) **Carney, L. L., N. Guven, and D. S. Panfil. Water-Base Mud System Having Most of the Advantages of Any Oil-Base System Plus Ecological Advantages SPE 17646, pres. at the SPE International Meeting on Petroleum Engineering in Tianjin, China, pp. 689-698, Nov. 1-4, 1988.**

ABSTRACT:

A medium pH range water base mud system designed as a result of high temperature high pressure studies on various clays and polymers has been laboratory developed and field tested. This type of system has proven to have advantages over water base mud systems previously used.

70) Bennett, R. B. New Drilling Fluid Technology - Mineral Oil Mud, Journal of Petroleum Technology, v.37,n.7, pp.975- 981, June 1984.

ABSTRACT:

The use of a paraffinic-based mineral oil, in place of the conventionally used diesel oil, as the continuous phase of an oil-based drilling and spotting fluid is a relatively new concept to the drilling fluid technology of the petroleum industry.

Mineral-oil-based fluids possess the same characteristics but also have definite advantages over diesel-oil-based drilling and spotting fluids. These characteristics and advantages are shown by laboratory evaluations, laboratory toxicity studies, and field case histories.

Laboratory toxicity tests have been conducted in other the U.S. and the U.K. Results show that mineral-oil-based fluids are considerably less toxic than diesel-oil-based fluids. Tests also indicate that oil retention characteristics of mineral-oil-based fluids are lower than diesel-oil-based fluids.

71) Wentz, C. A. Jr., and C. M. Shiver. Cleanup of Oilfield Wastes in an Environmentally Acceptable Manner, IADC/SPE 11402, pres. at the IADC/SPE 1983 Drilling conference held in New Orleans, La., pp.353-358, Feb.20-23, 1983.

ABSTRACT:

Treatment and disposal of drilling muds and hazardous wastes has become a growing concern in the oil and gas industry. Present disposal methods are either environmentally ineffective or increasingly expensive to use. Society's environmental protection opinions as well as rising trucking costs indicate a need for more effective and economical methods. Newpark waste treatment systems has developed an innovative technology which through field testing has proven to be both cost effective and environmentally acceptable.

72) Modesitt, L.E. Jr. Environmental Regulations: Leading the Way Toward Restructuring the Petroleum Industry?, Journal of Petroleum Technology, v.39, no.9, pp.1113-1118, Sept. 1987.

ABSTRACT:

Despite the promises of the Reagan administration to deregulate where practical and to reduce the number of new regulations, Congress continues to write and to enact more environmental legislation, and the U.S. Environmental Protection Agency (EPA) continues to develop more environmental regulations. The overall scale and impact of these regulations, largely ignored outside the affected industries, add greater momentum to the ongoing petroleum industry restructuring process.

It is clear that few, if any, government policy makers and legislators seem to have grasped the overall immediate and midterm impacts of these regulations on the petroleum industry. Even less well understood are the long-term impacts of continuing additional environmental regulatory requirements. In addition to the impact of more recent environmental laws; older statutes continue to place requirements on the industry. The Clean Air Act and the Clean Water Act and their accompanying regulations have changed substantially in the last decade. As well understood as they are, however, both the Clean Air Act and the Clean Water Act have a few surprises left.

73) Yearwood, J., J. C. Bolssler and B. Yidick, Paper No. 88-39-105, pres. at 39th Annu. CIM Petrol. Soc. Tech. Mtg. & Can. Gas Processors Ass. 2nd Quart. Mtg. Preprints, v.3, pp.7, June 12-16, 1988.

ABSTRACT:

During drilling or cementing, lost circulation may be encountered due to the presence of highly permeable formations, which may be due to high natural permeability in a sandstone, or to large natural fractures and vugs as found in limestones. This problem is critical as it increases the drilling costs due to wasted time, plus the possibility of stuck pipe and even losing the well. In most cases, viscous mud pills with lost circulation material, gel, etc., allows to temporarily reduce the losses but does not guarantee a durable plugging of the formation. Cement plugs can be used but their placement and the time necessary

to drill through them make their use relatively costly.

A high pressure experimental set up was used to plug various cores of different permeabilities and with different saturation fluids. Results are presented on the extrusion resistance obtained after one hour and after one week. This gel is shown to withstand differential pressures greater than 1500 psi per foot of plugged formation. Some results on the long term stability of this gel to aggressive brines, organic compounds and oil are included.

74) **Yosle, T. F. Environmental Challenges Will Need Cooperative Solutions, OJG Report, Oil and Gas Journal, pp.59-74, Nov. 14, 1988.**

ABSTRACT:

What are the major environmental challenges facing the petroleum industry, now and in the near future? There are at least four:

- Developing better scientific information, technologies, and analytical techniques to solve environmental problems
- Improving public access to information on petroleum operations and products and increasing public confidence in such operations and products.
- Linking environmental protection with other important national goals such as enhancing our competitiveness in international markets, improving the balance of trade, and improving productivity
- Developing and articulating a strategy to more effectively participate in the public debate over environmental policy and devising constructive solutions in partnership with the government and the citizenry

75) **Klemt, B. S. Pole and R. MacKinnon. Industrial Waste Disposal Wells "Mechanical Integrity", Proceedings of the Symposium on Subsurface Injection of Liquid Wastes, pp.90-112, March 3-5, 1986.**

ABSTRACT:

A review of case histories of injection well failures indicate that most failures involved (a) the injection of acid wastewaters which caused pressurization of the disposal reservoir and/or deterioration of the injection well itself; (b) the lack of a systematic mechanical integrity testing program tailored to the individual waste disposal well; (c) well number of mechanical integrity testing methods to provide definitive information regarding locations of leaks in the casing, tubing, or packer, and fluid movement behind the casing.

76) **Leuterman A.J.J., F. V. Jones , G. W, Bettge and C. S. Stark. New Drilling Fluid Additive Toxicity Data Developed. Offshore , July 1989. pp. 31-36.**

Abstract:

Major mud companies present comprehensive data to assist in environmental compliance efforts. The data were obtained from three major drilling fluid companies and were based on bioassay test results conducted by both in-house and independent, commercial laboratories. All tests were conducted in accordance with established EPA protocols. This testing protocol identified eight generic fluids that generally define the range of mud formulas used in the Gulf of Mexico.

77) **Lee, M. D. and C. H. Ward. Biological Methods for the Restoration of Contaminated Aquifers, Environmental Toxicology and Chemistry, v.4, pp. 743-750, 1985.**

ABSTRACT:

Contamination of aquifers is a serious threat to groundwater supplies. Once an aquifer is contaminated, it may remain so for many years. Biological methods for restoring aquifers polluted by organic compounds offer a promising solution. Techniques such as in situ treatment by stimulating the indigenous microbial population or withdrawal of the contaminated groundwater and treatment by conventional wastewater treatment processes have been used successfully. Mutant and acclimated microorganisms can be used in these systems in attempts to increase the rate of degradation of

recalcitrant compounds. Stimulation of the indigenous microbial population by the addition of oxygen and nutrients has been shown to be effective in the removal of petroleum products, iron and manganese, and organic solvents. Acclimated and mutant strains of bacteria have been inoculated into treatment reactors and into soil to degrade various organic chemicals. Polluted groundwater also has been withdrawn and treated by activated sludge processes. While some of these processes have not been adequately tested under field conditions and may be limited in applicability, biological methods are effective in restoring some contaminated aquifers.

78) **Watson, J. S. and C. D. Scott. The Impact of Bioprocessing on Enhanced Oil Recovery, OAK RIDGE NATIONAL LABORATORIES DE88-006985, pp.55, March 1988.**

ABSTRACT:

Biotechnology can, and is likely to, play an important role in many aspects of microbial-enhanced oil recovery (MEOR). Most current research is directed toward in situ production of surfactants, polymers, and other materials that can enhance the recovery of oil by altering the water-oil interfacial properties or viscosities or the bulk flow patterns in the field. The mechanisms of MEOR are still not well understood, and better evaluations of the relative merits of in situ and surface production of these chemicals that enhance oil recovery are needed. Field tests of MEOR must be planned and executed to increase our understanding of MEOR results.

Other potential uses of biotechnology to enhance oil recovery have been identified and should be explored. This report reviews current MEOR studies and assesses the additional roles which biotechnology is likely to have in future oil recovery operations. For example, the use of microbial action to reduce environmental problems from release or reinjection of floodwaters could become very important if current exemptions of oil recovery operations from environmental regulations are not extended.

79) **Shalala, T. P. and R. E. Kamat. A Potential Leaching Method for the Study of the Mobility of Organic Constituents in Drilling Fluid Wastes, 2nd Okla. Univ. Drilling Muds National Conference, pp. 178-204, May 28-29, 1987.**

ABSTRACT:

Although the ground water pollution potential of metals in waste drilling fluids has been researched extensively, the potential from organic constituents contained in these fluids has lacked adequate research. One major reason for this lack of intensive research concerning organics has been the absence of an adequate extraction method for organics in sludges and other liquid wastes. The U.S. Environmental Protection Agency (EPA) recently released a new leaching procedure, the Toxicity Characteristic Leaching Procedure (TCLP), designed to accurately model the mobility of constituents from wastes, particularly organic constituents. The specific environment modeled by the TCLP is codisposal of industrial waste with refuse in a sanitary landfill. Tests were run in order to verify the reliability of the TCLP in modeling the mobility of organic constituents of drilling fluid wastes in an on-site disposal pit as opposed to industrial wastes in a sanitary landfill. Column leachability tests were first performed to determine the attenuation of C-14 phenol. The TCLP was also performed using drilling fluid wastes from the same site. This paper presents a comparison of the data from the TCLP and column leachability tests.

80) **Wally, R. F. and P. O. Clark. Treatment of Oil and Gas Wastes In an Environmentally Acceptable Manner, 2nd Okla. Univ. Drilling Muds National Conference, pp. 123-127, May 28-29, 1987.**

ABSTRACT:

Increasing federal and state environmental regulations on the disposal of nonhazardous and hazardous oilfield and industrial wastes have caused an increase in the cost and awareness of this phase of the oil business. With the current depressed state of the oil industry, operators are looking for the most economical way of managing their wastes, while also complying with environmental issues.

After years of research and field testing, Newpark has developed a process that can economically treat wastes from the oil and gas industry in a manner consistent with environmental protection. The process, which has been proven by many years of operation, uses chemical, electrical, and mechanical means to separate the waste drilling fluids into two environmentally acceptable products: a relatively dry,

non-leachable, cake-like solid which has been approved for reuse, and water, which is purified, then recycled or discharged directly. This process has been successfully used for water-base and oil-base drilling fluids from offshore as well as land.

- 81) **Marks, R. E., S. D. Field and A. K. Wojtanowicz. Oil Reduction In Drilling Wastes By Biological Treatment, 2nd Okla. Univ. Drilling Muds National Conference, pp. 78-104, May 28-29, 1987.**

ABSTRACT:

The State of Louisiana requires elimination of the large number of oil-laden sludge pits which are located in the petroleum producing areas of the state. The majority of these pits are not readily amenable to conventional closure methods due to high oil concentrations and solids handling problems. This paper describes a laboratory research effort which resulted in successful biodegradation of the majority of the oil and grease fractions from slurries containing up to 76 percent sludge. Improved handling characteristics of the biodegraded solids were demonstrated. This research program has indicated that heavy sludges can be readily biodegraded and, after further upscale testing, may prove to be a low-cost alternative for elimination of the pressing Louisiana sludge disposal issue.

- 82) **Rutberg, R. J., D. G. Colley and G. M. Smolarski. Applications of Thermal Incinerators in the Petroleum Industry, pres. at the Pacific Coast Oil Show and Conference, 10 p., Nov. 4-6, 1986.**

ABSTRACT:

Disposal of waste gases from petroleum production must be economical, efficient and practical. Atmospheric release of waste gases through direct venting or incomplete combustion may impact on the local environment or residents. Combustion of the waste gases in thermal incinerators is a practical means of disposal when the waste gas contains noxious compounds that may cause odors or adverse health effects.

The petroleum industry presents a number of waste gas sources that require special consideration for incineration. Low pressure and fluctuating flow rates make premixing of waste gas difficult. In addition, low waste gas heating values retard efficient combustion. These difficulties have been addressed in thermal incinerators and both steam and combustion driven heavy oil in-situ recovery schemes.

Test results from operating incinerators confirm virtually complete combustion of the waste gases, conservation of fuel gas (where required) and reliable performance. Such results demonstrate the acceptability of thermal incineration technology in the petroleum industry.

- 83) **Calloway, J. M. The Stabilization of Drilling Muds. Drilling Muds National Conference, Norman, Ok., May 29-30, 1986. pp. 172-177.**

ABSTRACT:

Stabilization of drilling muds is discussed along with a presentation of data on the EPA Extraction Procedure and the proposed Toxicant Characteristics Leaching Procedure. Descriptions and data on three alternative operational approaches is included.

Historically, stabilization of drilling muds has been satisfactorily practiced by:

- 1) mixing with available soils at the well site; or
- 2) adding lime, portland cement, etc. to the point of rejection in a drilling mud pit while mixing with a backhoe, etc.

However, with the changing regulatory and economic climate, further refinement of these methods seems appropriate. This paper addresses potential refinements in stabilization systems.

- 84) **CPI Go Below to Remove Groundwater Pollutants, Chemical Engineering, v.93,**

11, pp.14-19, June 9, 1986.

ABSTRACT:

Much of the current activity centers around in situ aerobic biodegradation (also called bioreclamation), which will be used at more than 100 sites for treating organic chemicals as diverse as petroleum-derived hydrocarbons, hydrocarbon solvents, various aromatics, oxygenated compounds (C1-C6), and simple amines.

By feeding nutrient solutions and oxygen to natural soil bacteria, this method enhances the organisms' ability to degrade organic molecules into carbon dioxide and water. Researchers at government and industrial laboratories also are experimenting with artificially mutated bacteria to make them more active and selective to such hard-to-destroy chemicals as chlorinated pesticides, polyhalogenated aliphatics, and dioxins and polychlorinated biphenyls.

In addition, two traditional approaches to groundwater cleanup - air stripping, and adsorption on activated carbon - are getting some new twists. For example, air stripping at temperatures of up to 150° F is doubling and tripling the amounts of non-volatile organic compounds that can be removed, compared with stripping at ambient temperatures. And a number of companies are introducing new activated-carbon grades that are more selective for certain organic compounds, such as trichloroethylene.

85) **Atlas, R. M. Biodegradation of Hydrocarbons In the Environment. Environmental Biotechnology, pp. 211-222, 1988.**

ABSTRACT:

Studies on the environmental fate of petroleum have demonstrated the nearly ubiquitous distribution of microorganisms that can metabolize hydrocarbons. The rates of degradation depend upon the concentrations of such microbes and upon the environmental characteristics of an oil-contaminated ecosystem. Given the appropriate environmental conditions, microorganisms effectively decontaminate, by their biodegradative metabolism, environments that have received petroleum pollutants.

86) **Eyman, L.D. and T.D. Anderson Innovative Technologies for the Treatment of Hazardous and Mixed Wastes, OAK RIDGE NATIONAL LABORATORIES CONF-880510-1, 12 pp.**

ABSTRACT:

The treatment, storage, and disposal of hazardous and mixed wastes incur significant costs for Department of Energy (DOE) installations. These wastes must be managed under strict environmental controls and regulations to prevent the possibility of migration of hazardous materials to the biosphere. Through the Hazardous Waste Remedial Actions Program, the DOE is seeking to develop innovative ways of improving current treatment technologies to eliminate the hazardous components of wastes, reduce waste management costs, and minimize the volume requiring disposal as hazardous or mixed waste. Sponsored projects progress from research and development to field demonstration. Among the innovative technologies under development are supercritical water oxidation of hazardous chemicals, microwave-assisted destruction of chlorinated hydrocarbons, paramagnetic separation of metals from destruction through calcination, treatment/disposal of reactive metals, and methodologies for encapsulation. Technologies at a demonstration phase include detoxification of mixed waste sludge, microbial degradation of polychlorinated biphenyls in soil, and the remediation process for a hydrocarbon spill.

87) **Glaser, J.A. Promising Technologies for the Biological Detoxification of Hazardous Waste, EPA/600/D-88/040, 12 pp., February 1988.**

ABSTRACT:

A number of new biological technologies that target the cleanup of contaminated hazardous waste sites are under development. These technologies utilize specific organisms to degrade organic chemical contaminants to less toxic species. Two areas of development that will be discussed in this paper are the use of a white rot fungus wood degrader for water and soil treatment of wood treating wastes.

88) Boesch, D.F., et. al. Long-Term Environmental Effects of Offshore Oil and Gas Development, 708 pp., 1987.

SUMMARY:

Summary of the potential long-term environmental effects of offshore oil and gas development activities which are of high priority for future investigation

High priority:

- Chronic biological effects resulting from the persistence of medium and high molecular weight aromatic hydrocarbons and heterocyclics and their degradation products in sediments and cold environments
- Residual damage from oil spills to biogenically structured communities such as coastal wetlands, reef and vegetation beds
- Effects of channelization for pipeline routing and navigation on coastal wetlands

Intermediate priority:

- Effects of physical fouling by oil of birds, mammals and turtles, especially in species in which a large percentage of the population aggregates at certain times
- Effects on benthos of drilling discharges accumulated through field development
- Effects of produced water discharges generated offshore but discharged into near shore environments

Low Priority:

- Effects of noise and other physical disturbances on populations of birds, mammals and turtles
- Reduction of fishery stocks due to mortality of eggs and larvae as a result of oil spills
- Effects of man-made, usually gravel, islands and causeways in the Arctic on benthos and anadromous fish species.

Study needs related to the long term fate of sediment-associated contaminants resulting from offshore oil and gas development

Drilling fluids and cutting discharges

1. Flume studies on threshold movement of the settleable fraction of drilling fluid and drilling fluid ambient sediment mixtures.
2. Studies on threshold movement as a function of biotic activity (i.e., biological "packaging"; biogenic structures).
3. Studies on the vertical mixing of drilling fluids into the sediment column and then resuspension due to bioturbation.
4. Microscopic studies of the postdepositional "packaging" and other physical transformations of drilling fluid particles.
5. Transformation of heavy metals and organics from sorbed to dissolved state in oxic and anoxic sediments.
6. Partitioning of heavy metals and organics between aqueous and solid phases during mixing with sea water as a function of drilling fluid concentrations in sea water.
7. Studies on the association of metals and organics with different particle sizes within the drilling fluid mixture.
8. Characterization of organic compounds other than nonhydrocarbons in drilling fluids.
9. Quantification of formation-related hydrocarbons (shales) that may be introduced and deposited with drill cuttings, and the postdischarge partitioning of these formation hydrocarbons between sea water and particles.

Formation water discharges

1. The full characterization of organic compounds and metals in a variety of "typical" formation waters.
2. The partitioning of these compounds between particulate and aqueous phases, for different formation waters and particle concentrations.
3. Studies on the postdepositional fate of formation water contaminants, including biodegradation and partitioning into sea water.
4. Bioavailability and depuration by filter-feeding and detrital-feeding bivalves.

Oil spills and discharges

1. Studies on the association of petroleum hydrocarbons with different particle types and concentrations as a function of oil concentration and type (heavy and light crudes).
2. Mass balance studies to quantify the amounts of oil expected to be sedimented under differing suspended particulate concentrations.
3. Rates of hydrocarbon degradation as a function of 1) sediment oxygenation, 2) background hydrocarbon concentration, 3) background microbial populations abundance and 4) hydrocarbon molecular type.
4. Release of sedimented petroleum compounds into pore waters and overlying waters.
5. Bioavailability and depuration by filter-feeding and detrital-feeding bivalves.

RECOMMENDATIONS:

Long-Term Monitoring Programs

1. Additional long-term investigations of the fate and biological effects of drilling fluids and cuttings discharges from exploratory rigs are not warranted, except when exploratory drilling is proposed for a particularly vulnerable area or there is substantial reason to believe an inherently valuable resource is in jeopardy.
2. A long-term effects program should be performed during intensive development of a new offshore oil field in a frontier area. The area should be on the continental shelf in a low to medium-energy depositional area, preferably away from major influence of other sources of pollution or riverine inputs. Candidate areas include the Santa Maria Basin, California and the east Texas-west Louisiana shelf. Candidate areas in the Bering Sea off Alaska may be identified in the future.

Information Needs

1. Little research has been performed on the fate of organic components of drilling mud following discharge of drilling mud to the ocean. Of particular concern are lignosulfonates and their degradation products and hydrocarbon lubricants, which have been identified as the most toxic components of water-based drilling fluids. Laboratory and field studies should be performed to determine if these additives remain with the light surface plume or with the rapidly-settling fraction of discharged drilling fluid. If a significant fraction of these material remains with the settleable fraction, what are their persistence in and bioavailability from bottom sediments?
2. Our knowledge of the composition of produced water from different coastal and continental shelf sources is inadequate. More careful analyses of metals in produced water should be performed, with adequate correction for or consideration of interference from the brine matrix, or using methods that are less sensitive to matrix effects. More information is needed on the concentrations of aromatic hydrocarbons with molecular weights greater than that of naphthalene in treated produced water, particularly from oil fields. The composition of the large nonvolatile soluble organic fraction of produced water is largely unknown and should be characterized by sophisticated techniques, probably gas chromatography/mass spectrometry.
3. The environmental fate of produced water ingredients, particularly in shallow coastal area, should be investigated further. Of particular concern are several metals (arsenic, copper, lead, mercury, and zinc), radionuclides (^{226}Ra , ^{228}Ra), aromatic hydrocarbons (naphthalenes, phenanthrenes, dibenzothiophenes, etc.), and any toxic chemicals identified in the nonvolatile soluble organic fraction. Speciation and ultimate chemical form of produced water metals following discharge to the ocean should be investigated. Radium isotopes may be present in produced water at concentrations more than two orders of magnitude higher than in ambient seawater. ^{226}Ra may be useful as a tracer of the dilution and fate of the soluble fraction of produced water.

4. Long-term bioavailability of metals, radionuclides, aromatic hydrocarbons and soluble organics from produced water should be investigated. Additional, more carefully performed acute and chronic, sublethal bioassays should be performed with produced water from different sources.

5. Since it is generally agreed that any impacts of drilling fluid discharges will be restricted to the benthos where drilling fluid solids accumulate, solid phase bioassay protocols should be developed to more realistically evaluate the toxicity of drilling fluid solids to benthic organisms. Environmentally realistic and interpretable standard bioassay protocols are needed for certification and acceptance of generic muds and new mud additives and formulations as specified in NPDES permits.

89) Blodeterioration of Oil Spills (Jan 70 - Apr 89) Citations from the NTIS Bibliographic Database National Technical Information Service, Springfield, VA Report period covered: Jan 70 -- Apr 89) PB89-861611

This bibliography contains citations concerning the degradation of petroleum products, including hydrocarbons, oil spills, and beach pollution. Microbial degradation of petroleum products on land, on the surface of the water, and underwater are discussed. Composting techniques and genetic engineering to facilitate oil degradation are briefly cited. The effect of cold climates on degradation speeds is studied. This updated bibliography contains 213 of which 13 of which are new entries to the previous edition.)

90) Robertson, M. R. and Collins, G. A Corporate Waste Management Program: A Petro-Canada Inc. Perspective, Latin Amer. Hydrocarbon Congr., v.17,no.3, pp.271-281, Sept. 1988.

ABSTRACT:

This paper examines the need for an initiative to be taken in establishing a corporate waste management program for petroleum operations. Using the Petro-Canada experience as an example, a model is presented for developing a systematic approach toward identifying and resolving industrial waste concerns. The model components include developing a company waste management profile; organizing and implementing a company waste inventory; preparing waste management procedure; influencing strategic corporate directions; assessing the economics of waste disposal technologies and waste minimization; and implementing corporate waste management strategies.

91) Allen, T. R. and D. G. Austin. Apparatus and Method for Processing Oil Well Brine, U. S. 4,804,477, c.2/14/89, f.3/10/86, (appl. 838,179).

ABSTRACT:

An apparatus and process are described for the controlled concentrating of oil well brine. The apparatus is adapted to be situated at a wellsite where brine is produced. The apparatus provides a heating means for evaporating water from the brine to cause precipitable salts to precipitate out of solution and to be recovered and to cause the remaining liquid to become concentrated with soluble trace elements or minerals, which also are recovered. The brine does not have to be transported from the well site for processing, thus eliminating the possibility that a well may have to be shut-in due to the brine storage facility being full or due to no brine transportation being available. Additionally, no large capital investment is required for a brine disposal facility. The salts and minerals in the brine are recovered and sold, and the environment is not affected adversely.

92) Field, S. D., L.Forbes, R. E. Marks, and A. K. Wojtanowicz. Biological Treatment of Oilfield and Petrochemical Hazardous Wastes, pres. at the Engineering Foundation Conference on Biotechnology Applications In Hazardous Waste Treatment, Longboat Key, Florida, Oct. 30 - Nov. 4, 1988.

ABSTRACT:

The overall objective of this research program is to examine the feasibility of using a heterogeneous microbial population acclimated to petroleum and petrochemical waste sludges to degrade the complex hazardous organic substrates found in these wastes. This paper presents the preliminary results on the determination of: microbial population stability for two API separator sludges, and specific growth rates and substrate utilization measured for dodecane (C-12), hexatriacontane (C-36), and an API separator sludge.

The results obtained thus far on the biological treatability of petroleum and petrochemical wastes are very encouraging. The growth rates obtained on API separator sludge oil are well within the requirements for efficient process design for reducing oil content of the sludges. Substrate utilization at low concentrations indicates that process design can achieve quality effluent and waste solid streams. Further work needs to be expended on the fate of the principal hazardous constituents present in the sludges. Additional work on complex substrate availability, substrate destruction, kinetics of reactions for process design and scale up, and environmental growth limitations concern for a specific waste stream. Continuous loading experiments demonstrate an ability to maintain an effective change with different waste sources; this factor needs to be addressed further to determine the potential implications for those waste streams that have temporally variable composition.

93) **Redwelk, R. J. Jr. Drilling Waste Disposal Practices In the Gulf of Mexico, pres. at Annual AIChE Mtg., New York, 14 pp., Nov. 15 - 20, 1987.**

ABSTRACT:

The drilling waste disposal practices in the Gulf of Mexico are affected by the Environmental Protection Agency's General NPDES (National Pollutant Discharge Elimination System) Permit which is currently in effect. This permit allows the discharge of water-based drilling fluids and cuttings, subject to a toxicity limitation as well as other permit requirements. Of prime concern to the companies drilling in the Gulf are the handling and disposal of those fluids which cannot be discharged off shore. The current drilling waste disposal practice is to haul the drilling waste to shore for land treatment and/or disposal. The review of the current practice includes discussions on current (and Proposed) technologies, waste handling practices, associated costs, and the applicable regulations for each option. The proposed technologies are only highlighted in the discussion.

94) **Parker, H. W., K. A. Rainwater, and J. R. Edison. In Situ Oxidation to Decontaminate Soils and Aquifers Contaminated With Crude Oil or Petroleum Products, pres. at the Annual AIChE Meeting, New York, 33 pp., Nov. 15-20, 1987.**

ABSTRACT:

In situ oxidation with air is a simple and economic approach to the rehabilitation of soils or aquifers contaminated with crude oil or petroleum products. Biological oxidation is being used currently. Chemical oxidation with air is investigated in this research for use in aquifers where biological oxidation is not readily accomplished. Experimental measurements were focused on one crude oil-sand system: Lubbock County, 27° API gravity, with oil and 10% saturation with water. The materials were mixed together and packed in 150-mL sample containers, and then pressurized to 642 kPa with air and placed in constant temperature baths. The oxygen and carbon dioxide concentration of the contained air was analyzed, and then the cell was repressurized with fresh air periodically. After 20 to 70 days, steady-state oxidation rates were achieved.

95) **Jennings, A. R. Jr. Method for Suspending Wells, U.S. 4,819,727, c. 4/11/89, f. 7/21/86, (Appl. 492,185), (15 pp. 12 claims).**

ABSTRACT:

A method is described for shutting in an oil or gas well, which method minimizes formation damage. A solidifiable, pumpable gel mixture is placed via a well bore into the formation's productive interval and also within the well bore. The mixture solidifies in the formation and forms a gel plug within the well bore. Thereafter, a lightweight cement is placed over the gel plug to kill the well and suspend the production of oil and gas.

96) **Galaska, E. G., G. J. Skladany, and E. K. Nyer. Biological Treatment of Groundwater, Soils, and Soil Vapors Contaminated with Petroleum Hydrocarbons, pres. at the 44th Annual Purdue Industrial Waste Conference, West Lafayette, Indiana, May 10, 1989.**

ABSTRACT:

Biological methods have had wide application in the remediation of sites contaminated with petroleum hydrocarbons. This technology used the action of naturally occurring microorganisms to aerobically metabolize the contaminants present, usually converting the organic compounds into carbon dioxide, water, and additional bacteria. Above-ground and in-situ biological treatment of contaminated gasoline service stations and oil terminals has been quite successful, since most petroleum constituents are biodegradable. Further, biological treatment can cost-effectively and efficiently destroy the specific hydrocarbons present, thus eliminating potential future liability problems associated with other remediation technologies. This paper will present several case histories describing the biological treatment of petroleum hydrocarbon contaminated groundwater, soils, and air emissions.

97) **Torpy, M. F., H. F. Stroo, and G. Brubaker. Biological Treatment of Hazardous Waste, Pollution Engineering, v.21, n.5, May 89.**

ABSTRACT:

The controlled destruction of hazardous materials by natural methods in biological treatment offers unique and extremely diverse opportunities for the cleanup of contaminated environments. Biological treatment of hazardous materials is important because the results of treatment are usually innocuous materials such as biological cell mass and carbon dioxide, thus eliminating potential latent liability of the "treated" waste. Applications of biological treatment are becoming increasingly important in the field of hazardous waste treatment. This article discusses some basic concepts of biological treatment, and reviews some basic concepts of biological treatment, and reviews some of the more prominent techniques applied to hazardous waste site cleanup. The article also discusses some of the significant non-biological issues which must be addressed to understand the feasibility of using biological treatment.

98) **Sutton, Mark, M. M. Sutton and Associates (Oakland, California). Solar-Powered UV/Thermal Treatment System for Contaminated Soils, The Hazardous Waste Consultant, p. 1-7, May/June 1989.**

ABSTRACT:

A system using solar energy to destroy hazardous organic wastes is being developed by VEDA Inc. of Alexandria, Virginia. The process can be modified to treat either liquid or solid waste materials, but current efforts are directed toward designing a system that can be used to detoxify soil contaminated with PCBs or dioxins. The soil treatment system, as envisioned, involves a two-step process. In the first step, thermal energy from the sun is used to volatilize organic contaminants, driving them from the soil. In the second step, both thermal energy and ultraviolet (UV) radiation are used to destroy the vaporized contaminants in a thermally enhanced photolytic degradation process.

99) **General Electric Develops Method for Determining True Costs of Waste Management - Including Future Liability, Financial Analysis of Waste Management Alternatives, The Hazardous Waste Consultant, p. 1-1, March/April 1988.**

ABSTRACT:

At last someone has developed a plausible method for estimating true hazardous waste management costs! Engineers and economists have always been able to estimate capital and operating costs for any waste management technique, but the hidden cost of future liability for corrective actions has been universally ignored. Now the Corporate Environmental Programs group of General Electric has produced a comprehensive workbook that established procedures for evaluating all hazardous waste management costs. In addition, software written for Lotus 1-2-3® that will actually perform the requisite financial analyses is included with the workbook.

100) **Maler, W. J., and E. L. Cussler, Treating Hazardous Wastes by Reversible Gel Absorption, The Hazardous Waste Consultant, p. 1-4, July/August 1987.**

ABSTRACT:

Researchers at the University of Minnesota have been testing a new process called "reversible gel absorption" for concentrating aqueous waste streams. The process uses crosslinked polymer gels that swell and collapse as a function of temperature or pH. When the gels swell, they absorb water from waste solutions and exclude the waste components. Initial results indicate that with further development this process could be a cost-effective alternative to membrane separation.

101) **Brubaker, Dr. Gaylen R. of Remediation Technologies, Inc. (Chapel Hill, North Carolina), Determining the Feasibility of In Situ Bioreclamation, The Hazardous Waste Consultant, p. 1-4, July/August 1989.**

A definite trend away from the traditional excavate-and-dispose remedies and toward in situ treatment of contaminated soil and water is evident in the current approach to the remediation of hazardous waste sites. In situ biological treatment, in particular, is increasingly suggested as a remediation alternative. However, practical experience in the design and implementation of biological treatment systems is limited. For this reason, it is often difficult to determine if bioreclamation is a viable alternative at a particular contaminated site.

A simple method to evaluate the feasibility of bioreclamation at a given site, based on information that is typically gathered during a remedial investigation, is presented in a paper.

102) **Kluitenberg, G. J., et al., Innovative Pressurized Liner System Reduces Leachate Transport, The Hazardous Waste Consultant, p 1-1, July/August 1989.**

In developing an alternative liner design, researchers at Iowa State University approached the problem of preventing breakthrough slightly differently. Instead of trying to construct a liner with lower hydraulic conductivity, they attempted to construct a liner with no hydraulic gradient across it. (Hydraulic gradient is the force which drives advective transport; in the case of a landfill liner, it is equivalent to the pressure above the liner.)

103) **H. J. Paap and H. D. Smith, Jr., asrs. Behind Casing Water Flow Detector -- U.S. 4,524,272, c. 6/18/85, f. 12/20/82 (Appl. 451,635).**

A method is described for measuring the location, linear flow rate, and volume flow rate of undesired water flow behind a well casing. The procedure includes irradiating borehole environs with high energy neutrons from a neutron source located in a well tool in the borehole. Gamma rays from the decay of an unstable isotope are detected with gamma ray detectors located in the well logging tool. Count signals representative of the detected gamma rays from at least one of the detectors are separated into at least 3 energy dependent signals.

104) **H. J. Paap, asr. Behind Casing Water Flow Detection. U.S. 4,580,050, c. 4/1/86, f. 7/25/83 (Appl. 516,502).**

A method is described for providing a signal representative of undesired water flow behind well casing. A well tool is employed that is sized for passage through a wellbore. The tool has a source of high energy neutrons, at least some of which have sufficient energy to cause a nuclear reaction $^{16}\text{O}(n,pp)^{16}\text{N}$, and at least 3 gamma ray detectors spatially arranged in a predetermined manner. The borehole is irradiated with high energy neutrons from the source. The gamma ray detectors detect gamma rays resulting from the decay of the unstable isotope ^{16}N comprising a portion of any undesired behind casing water flow present.

105) Williams, T. M. Measuring Behind Casing Water Flow, U.S. Environ. Protection Agency et al. Subsurface Injection of Oilfield Brines Int. Symp., New Orleans, LA, 514-6187, Proc. pp. 468-484, 1987.

A common problem encountered in water injection operations is locating and stopping undesired water channelling. A behind casing water flow (BCWF) measurement system has been developed to measure vertical water flow in or behind multiple casings. This nuclear logging system can measure direction of flow, linear flow velocity, volume flow rate, and radial distance of the flow from the sonde. The system uses a neutron generator tube to provide a source of high energy neutrons to activate oxygen in the flowing water.

106) deRosset, W. H. M. Examples of Detection of Water Flow by Oxygen Activation on Pulsed Neutron Logs, 27th Ann. SPWLA Logging Symp., Houston, 6/9-13/86, TRANS. v. 2, Paper No. CCC, (25 pp; 5 refs), 1986

Upward flow of water in cased well bores may be detected with pulsed neutron capture (PNC) and gamma ray (GR) tools. Water entering tubing, casing and flowing behind pipe may similarly be evaluated qualitatively. Gamma ray background anomalies in PNC data and elevation of GR tool response occur when water is flowing above threshold velocities and volumes. The technique requires logging the well under static and flow conditions or logging at different tool speeds in a flowing well. Oxygen activation results in increased gamma ray count rates at each detector.

107) Engelhardt, F. R., J. P. Ray and A. H. Gillam, Drilling Wastes. Proceedings of the 1988 Int. Conf. on Drilling Wastes. Calgary, Alberta, Canada, April 5-8, 1988.

ABSTRACT:

This conference was the first time since 1980 that a broad evaluation of drilling wastes was carried out in a meeting forum. There have been many advances since 1980 in the treatment and control of drilling wastes and in the understanding of their environmental fate and effects. Further, changes have occurred in the methods of drilling for petroleum reserves, such as an increasing use of low-toxicity or alternate oil-based drilling muds. Advances have been made in both land and offshore operations of the petroleum drilling sector.

108) Anonymous, Remediation Technologies For Treating Hydrocarbon Contaminated Groundwater and Soil, An R, D and D Plan of Action. A report on a meeting held in Collingwood, Ontario, Nov. 28-Dec. 1, 1988. Report prepared by Markek Resource Consultants.

The Waste Water Technology Centre (WTC) of Environment Canada, in cooperation with the Industrial Programs Branch of Environment Canada and the Office of Environmental Affairs of Energy, Mines and Resources Canada, sponsored A Priority - Setting Workshop Concerning Research, Development, and Demonstration of Remediation Technologies for Treating Hydrocarbon Contaminated Groundwater and Soil. This Workshop was attended by 64 invited participants drawn principally from government, industry, and research organizations. The choice of most participants was based on their expertise in the area of contaminated groundwater and soil remediation. However, the core group was supplemented with additional non-technical participants who brought a cross-section of interests and viewpoints to the discussions.

109) Wolsko, T. D., J. L. Gillette, K. A. Hub, R. Kumar, R. W. Lyczkowski, V. A. Maroni, M. J. McIntosh, W. A. Mego, J. B. Rajan and D. R. Vissers. Novel Concepts For The Utilization of Fossil Resources. ANL/ES-156, Argonne National Laboratory, March 1988.

New approaches for increasing fossil resource utilization are needed in this century to insulate the United States from potential economic shocks resulting from increased prices or reduced foreign oil production. The objective of this project was to search for innovations that could provide improvements perceived to be better than the evolutionary improvements resulting from current technology research. The search was for radically different (revolutionary) ideas rather than evolutionary ideas. innovative ideas

ver generated in the following areas: direct and indirect liquefaction; oil shale; underground coal gasification; enhanced oil, heavy-oil, and tar-sand-bitumen recovery; Alaskan resources; and end-use concepts.

Appendix B -- In-house Panel Reviewers and Evaluation Summary.

IN-HOUSE WORKSHOP PARTICIPANTS

Mike Madden

Jim Pautz

Bill Johnson

Mike Crocker

Roy Porter

Min Tham

Subjects selected in preliminary search and ratings

	Rating*				
	1	2	3	4	5
• More rapid aquatic toxicity test				1	5
• More information on sublethal/chronic effects of chemicals in surface water discharges	3	1	2		
• Improved drilling solids removal process		1	4	1	
• Fate of toxic wastes				1	5
• Landfarming				2	4
• In situ treatment of wastes/soils			1	2	3
• Prevention of leaching of toxic materials from pits				3	
• Elimination of oil field waste pits		1	3	1	1
• New means of disposal of oilfield wastes		1	2	1	2
• Mechanical integrity - pumpable sealants		1	3	2	
• New completion fluid		1	2	3	
• Wastes removed as nonleachable form	1	2	3	1	
• Treatment of oilfield wastes using a rotating kiln	4	2			
• Treatment of drill cuttings slurries for environmental safe disposal (offshore)	3	2	1		
• Low toxicity oil-based drilling fluid			2	2	2
• Apparatus for removing oil from drill cuttings	2	3	1		
• Bioremediation					6
• Pit liner for wastewater pits	1	1	3	1	
• New sheen test	1	2	3		
• Method for cleaning soil contaminated with hydrocarbons	1	1	3	1	
• Drilling techniques	1	2	3		
• Centrifuge for rapid oil/water separation	1	4	1		
• Risk assessment of proper management of drilling wastes and produced water		3	2	1	
• Disposal of toxic heavy metals			1	2	3
• Systematic waste management			2	2	2
• New type mud		1	3	2	
• Better technology transfer, etc.			1	2	3
• Supercritical water oxidation of hazardous chemicals			3	3	
• Paramagnetic separation of metal from destruction through calcination		1	2	3	
• Encapsulation of wastes	1	2	2	1	
• Apparatus for processing oil well brine	2	3	1		
• In situ oxidation to decontaminate soils/aquifers	1	2	2	1	
• Oxygen-Activation Log					

5 is the highest priority rating.

*Rating by in-house panel.

Appendix C -- Sample Letter Used to Contact Experts For Additional Input.

(Current Date)

(Name and address)

Dear Mr. or Ms.

The National Institute for Petroleum and Energy Research is currently developing a program to assess environmental research development and demonstration needs related to oil and gas production. The objective of the program is to develop new research "ideas" that have the potential to improve the performance of oil and gas exploration, drilling, and production technologies for maximum recovery of domestic petroleum resources under optimal environmental and economic conditions.

The first phase of this program has been a search of current literature related to this subject. This search has indicated specific environmental areas that are in need of additional research. The second phase of the work is to coordinate this information and data with other researchers who are knowledgeable in the identified areas in order to provide additional insight.

One area that has been identified is In Situ Treatment of Wastes and Soils. In situ treatment of wastes and soils at contaminated sites offers an alternative to the traditional approach to site remediation involving excavation and redisposal, or onsite isolation. New techniques would offer a means for treating wastes involved in drilling and from other related oilfield practices. (This section changed to suit the person contacted.)

This is an area in which we feel that you could have additional input. Your contribution in this phase of our program would result in a more successful project and the satisfaction that some phase of the work that you suggest may be further studied by the Department of Energy and be of benefit to the environment.

Your cooperation in considering this phase of our research will be sincerely appreciated.

Sincerely,

Appendix D -- Experts Contacted Regarding RD&D Needs.

<u>Name</u>	<u>Affiliation</u>
J. Gall	Phillips Petroleum Company
E. C. Donaldson	University of Oklahoma
C. Goodner	Disposal Systems Inc.
P. S. Jones	Chevron Oil Field Research
D. Eno	Exxon Company, USA
D. Warner	University of Missouri
J. Lynn	UIPC
J. H. Robins	Amoco Corporation
W. T. Dowd	IOOC
H. Yates	Exxon Company, USA
B. Freeman	Shell Oil Company
J. Thornhill	U.S. EPA
R. L. Arscott	Chevron

END

**DATE
FILMED**

12/13/191