Pollution Prevention Opportunities in Oil and Gas Production, Drilling, and Exploration

Pacific Northwest
Pollution Prevention Research Center

Funded by a grant from the Pollution Prevention Office of the Alaska Department of Environmental conservation

The Pacific Northwest Pollution Prevention Research Center (PPRC) is a public non-profit foundation serving Alaska, Idaho, Oregon, Washington, and British Columbia. The PPRC sponsors research on pollution prevention, analyzes available technology, hosts forums, acts as an information clearinghouse, and serves as a link between public, and private groups.

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Above all, the PPRC wishes to thank the roundtable participants (listed in Appendix A) for their willingness to share the information, ideas, and suggestions which form the basis of this report.

Pollution Prevention Opportunities in Oil and Gas Production, Drilling, and Exploration

A Northwest Industry Roundtable Report

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Introduction

The Pacific Northwest Pollution Prevention Research Center (PPRC) held a roundtable discussion of pollution prevention in the exploration, production, and drilling segments of the oil and gas industry on December 4, 1992, at BP Exploration headquarters in Anchorage, Alaska. The purpose of the roundtable was to explore several areas relating to pollution prevention in the Alaskan oil and gas industry, including current industry practices, pollution prevention opportunities, potential areas for further research, and sources for information transfer. Participants included approximately 30 representatives from industry, regulatory agencies, academia, and the PPRC.

Funding for the roundtable was provided by a grant from the Pollution Prevention Office of the Alaska Department of Environmental Conservation (ADEC), which has been directed by state legislature to identify research needs for state business and industry. Meeting space and luncheon were provided by BP Exploration's Environmental Department.

Following a general discussion of pollution prevention, participants examined a number of waste streams generated during oil and gas production, drilling, and exploration. For each waste stream, group members provided overviews of current management practices for handling the waste, proposed alternative practices which might be pollution prevention-oriented, described any present experience with these new practices, and suggested possible research which could aid in designing, testing, or implementing these improvements. The results of these discussions are summarized in this report. Appended to the report are a list of participants and a bibliography of related readings.

Current industry practices

The initial introductions of the roundtable participants (see Appendix A) indicated a very professional and experienced audience representing companies and organizations that already had devoted much attention to incorporating pollution prevention practices and programs into their operations. Some of the participating companies' current pollution prevention/source reduction efforts are described below.

In the past, Doyon Drilling changed the oil in its generator sets every 500 hours. Now, by switching to a new oil filter system and a high base number oil, the engines can operate for 25,000 hours between changes. This practice has reduced the company's annual oil consumption by 80 percent.

At Atlas Wireline, all waters in the wash bay are recycled through a closed-loop oily water recycling system. The water stays in the wash bay, while the oil is burned in a generator that also supplies heat for the facility.

ARC0 has established company-wide Waste Minimization Committees at each business location that include representatives from various departments. Committee efforts have resulted in several successful programs including gravel washing, repair and reuse of pit-liners, and replacement of throwaway lube oil filters from vehicles with reusable ones. The company also participates in recycling programs for batteries and other materials and would support the creation of a clearinghouse for information on such programs.

BP. ARCO and Exxon each contribute a representative to a joint Waste Management Team which works on engineered environmental projects for the Prudhoe Bay oil field. Their projects are divided between "old waste" (for example, muds and cuttings stored in reserve pits) and "new waste" (camp wastes and other associated wastes). The Waste Management Team also tracks wastes by receiving regular reports on material sent out for disposal and options for its management. The team concentrates on permanent disposal, rather than short-term storage.

BPExploration is working with the Halon Alternative Research Corporation (HARC) to find replacements for halon (an ozone-depleting chlorofluorocarbon). In another research effort, BP is testing a process for washing contaminated gravel so it can be used as road building material.

Marathon Oil Company is focusing on improving control of materials, because the firm has found that better materials control reduces liabilities, management costs, and resource costs.

Conoco has formed a cross-disciplinary waste reduction team involving all levels of the organization. The team's purpose is to identify and characterize all waste streams generated by the company's operations and propose ways to reduce them.

MI Drilling Fluids has found that keeping smaller inventories of materials on hand reduced fluid waste. The company also recycles pallet boxes for five or six uses, instead of burning them or sending them to a landfill. Brines and drilling fluids are being recycled as well. The company has found that one type of fluid can frequently be converted into another, reducing liquid waste streams significantly.

After complimenting the participants on the activities described above, EPA Assistant Regional Administrator for Alaska Al Ewing proceeded to explain the EPA's position on pollution prevention. According to Ewing, prevention is now viewed by the EPA as the preferred approach to pollution, as it is both safer and less expensive than end-of-pipe control. These factors are especially relevant in the case of toxic pollutants present in trace amounts, a growing focus of the EPA. End-of-pipe control also fails to address what Ewing called "societal problems," which include smoke from wood stoves, automobile exhaust, and consumer product packaging.

The Pollution Prevention Act of 1990 reinforced this emphasis on pollution prevention. The Act directs EPA to incorporate pollution prevention into its existing regulatory activities, a focus EPA encourages at the state level as well. According to the EPA's definition, pollution prevention can include source reduction, equipment or technology modifications, process or procedure modifications, reformulation or redesign of products, substitution of raw materials, and improvements in housekeeping, training, maintenance, and inventory control. Ewing pointed out that relatively minor investments in some of these areas can have significant results, as demonstrated by the industry examples cited above. Not only can pollution prevention prove cost-effective for corporations, it has the added advantage of reducing many corporate liabilities. "It's not just the right thing to do," concluded Ewing. "It's the smart thing to do."

Robert Lipchak, ARC0 Alaska's Senior Waste Consultant, noted that the industry broadly defines pollution prevention to include elimination or reduction of all discharges to land, air, or water, whether by source reduction or closed loop recycling. The industry believes that properly designed, constructed, and operated waste disposal facilities also prevent pollution. Processes such as reduction of chlorinated solvents, evaluation of chemicals before use, recycling of hydrocarbons into the crude stream, and recycling gravels and drill cuttings as construction gravel for road and pad maintenance may all contribute to pollution prevention, stated Lipchak, and, as Ewing mentioned previously, they often prove cost-effective as well.

According to Lipchak, impediments to wide-scale pollution prevention in the oil and gas industry include a decline in industry profitability (resulting in reluctance to invest in funding for pollution prevention), the extractive nature of the business, the increase in waste quantities as fields age, the high transportation costs required to run reclaiming and recycling operations across Alaska's vast distances, and psychological resistance to change. However, concluded Lipchak, the industry is naturally supportive of efforts to make extraction more effective and to maximize the resource on which their business is based.

This general discussion of current pollution prevention issues and practices was followed by closer examination of specific industry waste streams, as described below.

Industry waste streams

Producedwater. Produced water, water produced in association with crude oil, is by far the largest waste stream in most oil fields, accounting for up to 95 percent of total wastes. It is composed of natural underground saline formation brines combined with water injected into the formations from the surface to enhance recovery of the oil in a process called "waterflooding." In mature fields like those of Alaska's North Slope, the amount of this water produced often exceeds the amount of oil. For the North Slope, that means more than 42 million gallons of produced water is generated daily. However, operations at second-generation oilfields such as the Kuparuk River Field reuse much of their produced water for enhanced oil recovery.

Presently as much as 60 percent of most, Alaska oil fields' produced water is treated to remove solids and traces of oil and then returned to the formation to be reused in water-flooding. The solids are removed during treatment, as their reinjection might plug the subsurface formation. Not all produced water is treated for continued waterflooding; some is only cleaned up sufficiently to reinject it for disposal in highly permeable zones at depths of several thousand feet. It was suggested that other industries may be able to provide improved technologies for handling produced water.

Miscellaneous surface waters. These waste waters include snowmelt and precipitation, non-exempt "relatively clean" waters such as some runofffrom cleaning vehicles and shops, and nonprocess industrial waste waters like engine coolant and unused cement slurry. These waste waters range from ones containing practically no contaminant (snowmelt, for example) to waters like cement slurries which clearly require treatment before they can be discharged or recycled.

There is at present no standard practice for recycling or disposing of these waste waters. Legal disposal is difficult and expensive without access to an industrial waste disposal well which can handle the injectant without well damage (such as that caused by cement slurry). Contaminants in these cases may be traces of hydrocarbon from small oil spills, or even the suspected presence of a non-exempt contaminant. As sampling to verify that the water is not contaminated is costly and time-consuming, these wastes are routinely treated as if they were contaminated. One roundtable participant proposed that a management study be conducted to identify best management practices (BMPs) for these waters using existing technology. Such a study could form a framework for ADEC and EPA to regulate wastewater disposal and recycling efficiently.

Rigwash falls into the category of low toxicity surface waste waters described above. The use of low toxicity detergents like citrulene and low toxicity cleaning methods used by the mining industry hold promise for reduction of this waste. A BMP might be developed which would 1) balance cost and convenience against environmental impact, and 2) define discharges not requiring an NPDES permit or RCRA regulation.

Drilling fluid (drill mid). Drill mud (also called cutting mud) is a complex colloidal mixture of water, bentonitic clays, chemical additives, and trace amounts of oil from cuttings of the hydrocarbon-bearing zones. This mud serves several purposes in oil drilling as it is circulated down the inside of the rotating drill from the surface and backup the annular space between the drill pipe and the drilled hole. At the drill bit/rock interface, it cools and lubricates the cutting action. As it flows up the annular space, it lifts rock chips which can then be screened out at the surface. Most important, the column of mud creates hydrostatic pressure which keeps pressurized oil or gas from being expelled uncontrollably (a “blowout”).

Much of this drill mud is recycled, but after repeated use it picks up fine rock particles and water soluble subsurface minerals until it is no longer economically practical to recondition it. The colloidal mass can then be separated from the water either by centrifugal processes or by simply allowing it to settle in a pit. The remaining fluid is then disposed of by deep injection. Much progress has been made in the last decade in the employment of low toxicity mud additives, which has enabled the EPA to issue NPDES permits for offshore discharges of treated muds and cuttings.

One roundtable suggestion was to investigate lower toxicity components or better reconditioning techniques. Several participants noted that more uniform drilling systems and chemical formulations in a single oil field or petroleum province might lead to more cost effective recycling of muds by avoiding the “customized” treatment required when multiple formulations are used. Another suggestion was to investigate the recycling of used muds or cuttings into masonry, tiles, bentonite caps for landfills, or other products.

Drill cuttings. Drill cuttings are the pieces of rock and soil removed from the ground as a drill bit cuts a hole for a well. Present technology for disposal of these cuttings is to bury them in a non-leaching lined landfill which freezes and becomes incorporated into the permafrost on the Alaskan North Slope. In at least one North Slope oil field, cuttings are ground using a ball mill. The ground material is then slurried and injected into a permeable subsurface formation.

BP and ARCO have undertaken several experimental recycling projects that involve washing the cuttings, testing to ensure that leachable chemicals approach background concentrations, and then recycling the washed material as construction gravel for road and pad maintenance. Sandra Hamann of ARCO Alaska and Janet Platt of BP Exploration both report considerable success with this process, although the amount ofwashing and chemical testing makes the procedure relatively expensive. Future research might evaluate environmental impacts of residual, leachable contaminants left on recycled, washed cuttings, as well as explore methods of reducing analytical costs which inhibit recycling.

Workover and completion wastes. Workover and completion wastes result from operations where an oil well's head is partially open to the atmosphere and is filled with a water base fluid that maintains pressure on the formation to prevent blowout. Workover fluid is injected into such a well while the well's interior tubing string, valves, packer gaskets, or other components are undergoing maintenance. When maintenance is complete, the workover fluid is removed from the well before starting routine operation. Completion fluids are typically used in a well when the well casing is perforated just before starting production. Both fluids become contaminated with oil and formation brine.

Standard practice for handling workover and completion wastes calls for separating the oil from the fluid and recycling both the oil and the fluid by filtering and adding more solute to make up for dilution by formation brine. Although the oil can easily be recycled, after several uses the base fluid can no longer be brought back to specification. Unreclaimable fluid is presently disposed of through subsurface injection, but better ways to recycle these fluids are currently being investigated by industry researchers. One technique to minimize excess fluid production is to use a continuous mix process, rather than a batch, producing only enough fluid to fill a well. Selection of fluid components that simplify this process, such as hydrogen sulfide scavengers, should encourage its use.

Proppants/frac sand. Proppants (also called "frac sand") refers to the aluminum silicate beads ofvarying sizes injected into wells to hold formation fractures open, thus increasing subsurface oil flow to the wells. When these materials are transported back to facilities with crude oil from the wells, the beads settle out, along with formation sand, to form a semi-solid sludge in the bottoms of vessels.

This proppant/frac sand now goes into lined landfills in South Alaska, but it has been suggested that the material could be sold as construction fill if it could be separated from the crude oil. Janet Platt of BP Exploration noted that BP considered constructing an oily waste facility that would have separated the recyclable solids from the oil, but the company cancelled the project because the $160 million cost was viewed as prohibitive. Roundtable participants also raised concern that less of this proppant/frac sand will likely be produced in the future, making recycling less feasible economically.

Bottom wastes. Tank bottom wastes are a type of sediment that accumulates in oil field vessels and pipelines when fluid turbulence is low. These dense sludges are composed of crude oil, paraffin, asphaltics, reservoir material, drilling mud, and slightly radioactive material (called NORM--"naturally occurring radioactive material"), in addition to the frac sand/proppant discussed above. Historically, bottom waste has been put into lined oily waste pits either for permanent burial or for temporary storage until it can be treated to remove hydrocarbons, usually by thermal processes.

As mentioned previously, BP designed a plant using solvent extraction to recover salable crude oil from bottom wastes, plus a recyclable solid for construction purposes. This waste stream was strongly suggested by roundtable participants as a subject for future research, as it represents a large, potentially toxic waste stream which is not recycled. Partially cleaned solids might be safely recycled by incorporating them into Portland cement or other materials for oil field applications. As with drill cuttings, determining acceptable levels of trace contaminants and methods of reducing analytical costs might also prove fruitful topics for research.

Dehydration and sweetening wastes. Polyols and glycols are used in the oil and gas industry as antifreeze additives and to remove traces of water from natural gas streams in the production of fuel gas. It was mentioned in the course of the roundtable discussion that waste dehydration polyols and glycols sometimes emit traces of benzene. Identifying an inhibitor chemical or process of benzene formation in these processes was suggested as a worthwhile research objective. A general study of how to reduce or inhibit contamination of triethylene glycol (TEG) and methyl ethyl glycol (MEG) streams, perhaps by using alternative dehydrating agents, might also be worthwhile.

Hydrogen sulfide (H_2S), a corrosive gas more toxic than hydrogen cyanide, is emitted by sulfate-reducing bacteria growing in subsurface formations and oil field surface equipment. The evolution of hydrogen sulfide is currently inhibited by using powerful biocides like acrolein and formaldehyde; unfortunately, these biocides are highly toxic and dangerous materials. The best way to avoid spills of these materials might be to institute a research and development project find an effective, but less toxic, biocide to use in their place.

Oily debris and filter media. Oily debris saturated with crude oil comes from oil spill cleanups (minor and major) and can include oily soil and gravel. Similarly, filter media which filter crude oil may become saturated with oil. Industry research has so far been unable to develop cost effective technology to remove and recycle the oil. Improved means of repairing, cleaning, and reusing oiled pit liners, sorbents, and plastics would be another possible research topic in this area.

Hydrocarbon wastes. Throughout the U. S., oil fields generate waste hydrocarbons such as "dirty diesel" fuel contaminated from pressure testing pipelines. Hydrocarbon waste is currently assesed for significant organic halides (which might poison refinery catalysts), filtered, commingled and processed with the crude oil stream from a field, and then sold to a pipeline. Upon arrival at the refinery, the waste fuel, in solution with the crude oil, is rerefined to useful products. This practice would benefit from increased public education and acceptance, simplified recycling regulations, and a review of liquid oil field wastes acceptable for recycling with little or no treatment.

Camp wastes. The participants pointed out that North Slope oil camps generate wastes equivalent in quantity to those of small municipalities. Many of these wastes can be easily recycled or reused: batteries can be segregated and recycled, radioactive smoke detector elements can be returned to the vendor for recycling, wood pallets can be recycled, fabric pit liners for temporary waste storage can be repaired and recycled, wood cribbing supporting temporary pipelines can be recycled, thread protectors from pipe ends can be recycled, reusable bins ("liquibins") can replace drums for chemical storage, reusable screens can be used for oil and air filters on vehicles, and vehicle lube oil can be recycled. In addition, in many camps new chemicals are reviewed before introduction to determine if less toxic substitutes are available.

Considerable environmental staff time is often spent on dealing with these wastes. A detailed literature review of municipal waste management or responsible military waste management at remote sites would be of value as a starting point for managing these camp wastes more efficiently. A review of waste exchanges and markets might be of use in handling such items as surplus paints, batteries, smoke detectors, and light bulbs. The notion of research partnerships with other industries was suggested, as was the idea of an "ombudsman" appointed by industry to operate a clearinghouse on waste management, exchange, and liability. It was agreed that some means of centralizing recycling efforts would allow for more cost-effective handling.

Halons and other CFCs. Large volumes of halon (an ozone-depleting chlorofluorocarbon) are currently being used in oil and gas production as a fire and explosion suppressant. The industry is currently seeking substitutes through the Halon Alternative Research Corporation (HARC), and dry chemical alternatives for halons are being tested. Freon, another CFC, is used in testing for total petroleum hydrocarbons, as well as in some cleaning operations involving electronic components. As with halons, effective substitutes are being sought, but further development ofrecommended testing protocols might prove helpful. HARC is also investigating the possibility of creating a recycling program for halons.

Garnet filter media. The large sea water filtration plants on the North Slope typically use garnet particles as filter media to remove suspended solids from sea water before the water is injected into the oil fields to increase oil recovery. Several tons of the inert, deep red, spent garnet filter media is generated each year, but no recycling options are currently viewed as feasible. Recycling the garnets as abrasives has been rejected due to the large size of the particles. Recycling as gravel pad material has been rejected for aesthetic reasons. One participant suggested that the garnet could be mixed into Portland cement or other similar compound and used as decorative building material.

NORM. Naturally Occurring Radioactive Material, or "NORM," is produced in solution with oil field brines and deposited as scale on the inside of oil field vessels and piping. Its radioactivity (rated as "low specific activity" by the Nuclear Regulatory Commission) poses a hazard if it is inhaled as a dry dust during vessel and pipe cleaning or repair. Recycling of this material is impeded by the lack of safe exposure levels. Further investigation into standards for exposure might prove beneficial.

Research recommendations

One obstacle to establishing research priorities for pollution prevention in oil and gas production can be a lack of sufficient data on quantities and relative toxicities of the various wastes produced. Clearly, bottom wastes saturated with crude oil, paraffin, and asphaltics are toxic, but many of the solids separable from these wastes (such as bentonite clay, garnet, frac sand, and aluminum silicate proppants) are virtually inert biologically. Some roundtable participants were concerned that considerable existing research effort may be focused on what are, in most cases, low toxicity sources.

A study quantifying mass, volume, toxicity, and environmental availability of the wastes outlined in this report would make it possible to rank their potential for environmental damage and to focus efforts for technical solutions. There seemed to be a general consensus in the group that produced water was massive in quantity, but relatively well handled by recycling and deep well disposal. Managing oily wastes and sludges in an economic and environmentally sound way, on the other hand, was seen as a very high priority issue. There was also a general consensus that a mechanism for more far-reaching communication on waste minimization, source reduction, toxics use reduction, and closed loop recycling should be instituted. This communication would encompass waste exchanges, technological transfer both within and between industries, and education of industry, government, and environmental groups to encourage cooperation on pollution prevention issues. Specific areas mentioned by the roundtable participants as suitable for research or educational projects include the following:

- Investigate more economical and efficient oil/produced water treatment systems for crude recovery.

- Identify best management practices for miscellaneous surface waters from existing technology which would form a framework to aid ADEC and EPA in efficiently regulating disposal and recycling.

- In collaboration with mud and drilling companies, investigate ways to standardize drilling systems and chemical formulations within single or geographically consolidated oil fields, which would make recycling of muds more practical.

- Explore the potential for recycling wastes into useful products, such as turning used muds into masonry, tiles, or bentonite caps.

- Examine the acceptable levels of contaminant for recycled solids (such as gravel, mud, or frac sand/ proppant beads) to be used as construction gravel to ensure they are in line with national risk-based requirements. Ways to streamline analysis and reduce analytical costs could also be investigated.

- Research recycling options for vessel bottom sediments containing low toxicity hydrocarbons. One option might be to recycle partially cleaned solids into Portland cement or other materials for oil field applications.

- Identify an inhibitor chemical or process of benzene formation in dehydration and sweetening processes. A general study of measures to reduce or inhibit contamination of triethylene glycol (TEG) and methyl ethyl glycol (MEG) streams, perhaps by using alternative dehydrating agents, might also be worthwhile.

- Research an effective, less toxic biocide or process that could be used in place of acrolein and formaldehyde to inhibit hydrogen sulfide emissions caused by sulfate-reducing bacteria in subsurface formations and on oil field surface equipment.

- Develop a best management practice with appropriate agency approvals for very small spills of toxics like acrolein and formaldehyde. Roundtable participants stated that these substances often vaporize or are naturally neutralized or diluted to nontoxic conditions so rapidly that current regulatory practices are viewed by industry as being disproportionately expensive and diverting resources from other important areas.

- Conduct a review of liquid oil field wastes which, with minor or no treatment, would be acceptable for recycling into the crude oil stream (with consideration of downstream impacts), and develop methods of encouraging such recycling. The use of vacuum trucks to transport recycled hydrocarbons for introduction into the crude oil sales stream is an example of a potentially useful practice which could be investigated for possible agency approval.

- Promote research partnerships with other industries and the military to investigate opportunities for managing wastes. This might be accomplished by establishing a clearinghouse on waste management, exchange, and liability.

- Investigate markets for recycling the several tons of spent garnet filter media generated each year.

- Recommend protocols for the testing ofalternatives to replace CFCs (chlorofluorocarbons). Current industry uses of CFCs include halon as a fire and explosion suppressant and freon as an extraction solvent in laboratory testing for hydrocarbons.

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Appendix B
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