Abstract

Environment, Pollution

ABSTRACT Each year, the oil industry generates millions of barrels of wastes that need to be properly managed. For many years, most oil field wastes were disposed of at a significant cost. However, over the past decade, the industry has developed many processes and technologies to minimize the generation of wastes and to more safely and economically dispose of the waste that is generated. Many companies follow a three-tiered waste management approach. First, companies try to minimize waste generation when possible. Next, they try to find ways to reuse or recycle the wastes that are generated. Finally, the wastes that cannot be reused or recycled must be disposed of. Offshore oil and gas operations generate a variety of solid and liquid wastes. Some of these wastes are attributable to exploration and production (E&P) activities (drilling wastes, produced water, treatment and workover fluids), while others are due to either human presence (sanitary wastes, food wastes) or generic industrial operations (wastepaper, scrap metal, used paints and solvents). This paper focuses on the E&P wastes, nearly all of which are disposed of in one of three ways — by discharge to the ocean, by injection into a dedicated injection well or into the annulus of a well being drilled, or by transport to a disposal site onshore. Here we look at the various techniques of drilling waste disposal. INTRODUCTION Oil field wastes are generated through well drilling, through the process of producing oil and ga.% and through associated activities. The drilling process generates two types of wastes — drilling fluids and &ii cuttings. Drilling fluids (or muds) are used to aid the drilling process. Muds are circulated through the drii bit to lubricate the bit and to aid in carrying the groundup rock particles (drill cuttings) to the surface, where the muds and cuttings are separated by mechanical means. Most onshore wells are drilled with water-based or oil-based muds, while offshore wells may also use synthetic-based muds. The American Petroleum Institute (API 2000) estimates that about 150 million barrels (bbl) of drilling waste was generated at U. S. onshore wells in 1995. When oil and gas are produced to the surface, they are accompanied by formation Water known as produced water. Produced water is generally salty and is the largest volume waste stream generated in the oil and gas industry. API (2000) estimates that almost 18 billion bbl of produced water was generated at U. S. onshore wells in 1995. Various other wastes, known as associated wastes, are generated through the process of collecting, treating, and storing oil and gas. Examples of these wastes are tank bottoms, soil contaminated by spills of produced water or crude oil, spent chemicals used to complete and stimulate wells, and pipe scale and sludges. API (2000) estimates that about 20 million bbl of associated waste was generated at U. S. onshore wells in 1995. How Are Wastes Managed? In 1988, the U. S. Environmental Protection Agency (EPA) determined that oil and gas exploration and production wastes (including drilling wastes and produced water) were exempt from the hazardous waste requirements of the Resource Conservation and Recovery Act (RCRA) [53 FR 25477]. In 1993, EPA concluded that associated wastes would also have the same exemption [58 FR 15284]. The federal government determined that state agencies were adequately managing the wastes and did not impose its own regulatory requirements. Therefore, regulation of oil field wastes is done at the state level. Most onshore oil field wastes are disposed of at the site of the well from which they were generated. Common practices are pit disposal or land spreading of drilling wastes and injection of produced water. At offshore platforms, most produced water and some drilling wastes are discharged to the ocean. Some wastes are sent to offsite commercial disposal facilities. Veil (1997) describes the various methods used to dispose of oil field wastes at such facilities. Different wastes are managed with different approaches. For example, produced water is most often managed through injection or evaporation, while drilling wastes and associated wastes are managed through a variety of methods, including: * land spreading * pits or landfills * evaporation * injection * incineration * salt caverns * treatment and reuse The Waste Management Hierarchy Historically, oil field wastes were managed in ways that were found to be most convenient or least expensive. Over the past decade, oil and gas operators have looked to waste management approaches that minimize the generation of wastes and to disposal techniques that offer greater environmental protection and public safety. A three-tiered waste management hierarchy is employed. In the first tier, processes are modified, technologies are adapted, or products are substituted so that less waste is generated. When feasible, waste minimization can often save money for operators and results in greater protection of the environment. For those wastes that remain following waste minimization, operators next move to the second tier, in which wastes are reused or recycled. An example from the oil field is injection of produced water not for disposal but to stimulate secondary production through a water flood. A second example is reuse of treated drill cuttings as landfill cover material. Some wastes cannot be recycled or reused and must be disposed of by the methods described in the previous section. For some of the disposal options, wastes are treated before disposal. Types of drilling waste The wastes most commonly associated with offshore E&P activities include: - Drilling fluids, - Drill cuttings, - Produced water, - Treatment, workover, and completion fluids, - Deck drainage, - Produced sand, - Naturally occurring radioactive materials (NORM), - Hydrostatic test water, and - Other assorted wastes Present Waste Disposal technology Onsite Burial (pits, landfills) Burial is the placement of waste in man-made or natural excavations, such as pits or landfills. Burial is the most common onshore disposal technique used for disposing of drilling wastes (mud and cuttings). Generally, the solids are buried in the same pit (the reserve pit) used for collection and temporary storage of the waste mud and cuttings after the liquid is allowed to evaporate. Pit burial is a low-cost, low-tech method that does not require wastes to be transported away from the well site, and, therefore, is very attractive to many operators. Burial may be the most misunderstood or misapplied disposal technique. Simply pushing the walls of the reserve pit over the drilled cuttings is generally not acceptable. The depth or placement of the burial cell is important. A moisture content limit should be established on the buried cuttings, and the chemical composition should be determined. Onsite pit burial may not be a good choice for wastes that contain high concentrations of oil, salt, biologically available metals, industrial chemicals, and other materials with harmful components that could migrate from the pit and contaminate usable water resources. PITS The use of earthen or lined pits is integral to drilling waste management. During most U. S. onshore drilling operations, the cuttings separated by the shale shaker are sent to a pit called the reserve pit located near the drill rig. The pit is generally open to the atmosphere, so it also accumulates stormwater and washwater from the rig. The strategic location of small pits near drilling sites can also help minimize spillage of waste materials. Unless site characteristics are such that no significant threat to water resources can occur, liners are generally required. Where pits must be constructed adjacent to water bodies or on sloping terrain, engineering precautions incorporated into the design will help to ensure pit integrity. Precautions should be taken to prevent disposal of chemicals, refuse, debris, or other materials not intended for pit disposal. At the end of the drilling job, any hydrocarbon products floating on top of the pits are recovered and any free water or other liquids are collected and disposed of, usually in an injection well. The remaining cuttings are covered in place using native soils, the surface is graded to prevent water accumulation, and the area is revegetated with native species to reduce the potential for erosion and promote full recovery of the area's ecosystem. Reserve pits should be closed as soon as possible following the generally accepted closure procedures in the region. LANDFILLS Landfills are used throughout the world for disposing of large volumes of municipal, industrial, and hazardous wastes. In landfills, wastes are placed in an engineered impoundment in the ground. At the end of each day or on some other cycle, the waste is covered with a layer of clean soil or some other inert cover material. Modern design standards require clay or synthetic liners, although, in some areas, unlined landfills continue to operate. Landfills can be used for disposing of drilling wastes and other oil field wastes. In some circumstances, these are offsite commercial operations established to receive wastes from multiple operators in an oil field (e. g., the West Texas region). In other cases, oil companies with a large amount of drilling activity in an area may construct and operate private landfills. For example, TotalFinaElf designed and built a controlled landfill to dispose of inert wastes at a remote site in Libya, where other management alternatives were not readily available. At this landfill, a bottom liner overlaid by a geological barrier was developed to prevent contamination of the soil. A top liner, which is drawn over the waste during non-active periods, will be installed permanently after the landfill is closed. Two collection pits collect rainwater and subsequent leachate . IMPLEMENTATION CONSIDERATION Wastes suitable for burial are generally limited to solid or semi-solid, low-salt, low-hydrocarbon content inert materials, such as water-based drill cuttings. Costs for disposing of cuttings that have been stabilized prior to dilution and burial are estimated at $9-10 per barrel of waste (Bansal and Sugiarto 1999). Factors to consider for burying drilling wastes include the following: * Depth above and below pit. Areas with shallow groundwater are not appropriate; a pit location of at least five feet above any groundwater is recommended to prevent migration to the groundwater. The top of the burial cell should be below the rooting zone of any plants likely to grow in that area in the future (normally about three feet). * Type of soil surrounding the pit. Low-permeability soils such as clays are preferable to high-permeability soils such as sands. * For offsite commercial landfills, any protocols required by the facility accepting the waste (not all facilities have the same acceptance criteria). * Prevention of runoff and leaching. Appropriate types and degree of controls to prevent runoff and leaching should be implemented. Natural barriers or manufactured liners placed between the waste material and the groundwater help control leaching. * Appropriate monitoring requirements and limits. * Time required to complete the burial. * Chemical composition of the buried cuttings. * Moisture content or condition of buried cuttings. The advantages of onsite burial of drilling wastes include the following: * Simple, low-cost technology for uncontaminated solid wastes. * Limited surface area requirements. Concerns include the following: * Potential for groundwater contamination if burial is not done correctly or contaminated wastes are buried, and the resulting liability costs. * Requirements for QA/QC, stabilization, and monitoring. * BIOREMEDIATION * Bioremediation (also known as biological treatment or biotreatment) uses microorganisms (bacteria and fungi) to biologically degrade hydrocarbon-contaminated waste into nontoxic residues. The objective of biotreatment is to accelerate the natural decomposition process by controlling oxygen, temperature, moisture, and nutrient parameters. Land application is a form of bioremediation that is described in greater detail in a separate fact sheet. This fact sheet focuses on forms of bioremediation technology that take place in more intensively managed programs, such as composting, vermiculture, and bioreactors. McMillen et al. (2004) summarizes over ten years of experience in biotreating exploration and production wastes and offers ten lessons learned. * Bioremediation decisions can be facilitated through the use of risk-based decision making (RBDM), a process that uses risk considerations to develop cleanup levels that are environmentally acceptable for the given characteristics and anticipated land use of a specific site. * Some advantages of biological treatment are: it is relatively environmentally benign; it generates few emissions; wastes are converted into products; and it requires minimal, if any, transportation. Sometimes, bioremediation is used as an interim treatment or disposal step, which reduces the overall level of hydrocarbon contamination prior to final disposal. Bioremediation can create a drier, more stable material for land filling, thereby reducing the potential to generate leachate. Depending on the composition of the hydrocarbon components, the bioremediation environment, and the type of treatment utilized, bioremediation may be a fairly slow process and require months or years to reach the desired result. * Composting In composting, wastes are mixed with bulking agents such as wood chips, straw, rice hulls, or husks to increase porosity and aeration potential for biological degradation. The bulking agents provide adequate porosity to allow aeration even when moisture levels are high. To increase the water-holding capacity of the waste-media mixture, and to increase trace nutrients, manure or agricultural wastes may be added. Adding nitrogen- and phosphorus-based fertilizers and trace minerals can also enhance microbial activity and reduce the time required to achieve the desired level of biodegradation. | | | Composting is similar to land treatment, but it can be more efficient. Also, with composting systems, treated waste is contained within the composting facility where its properties can be readily monitored. With composting, mixtures of the waste, soil (to provide indigenous bacteria), and other additives may be placed in piles to be tilled for aeration, or placed in containers or on platforms to allow air to be forced through the composting mixture. To optimize moisture conditions for biodegradation, the compost mixture is maintained at 40 to 60% water by weight. Elevated temperatures (30 to 70 degrees C) in compost mixtures increase microbial metabolism. However, if temperatures exceed 70 degrees, cell death can occur. Tilling the soil pile or forced aeration can help control temperature and oxygen levels. Composting in closed containers can control volatile emissions. Composted wastes that meet health-based criteria can be used to condition soil, cover landfills, and supply clean fill. McMillen and Gray (1994) reported estimated costs for windrow composting of exploration and production wastes to range from $40 to $70 per cubic meter. Bioreactors * Bioreactors work according to the same aerobic biological reactions that occur in land treatment and composting, but the reactions occur in an open or closed vessel or impoundment. This environment accelerates the rate of biodegradation by allowing better control of the temperature and other conditions that affect the biodegradation rate. Bioreactor processes are typically operated as a batch or semi-continuous process. In a bioreactor, nutrients are added to a slurry of water and waste, and air sparging or intensive mechanical mixing of the reactor contents provides oxygen. This mechanical mixing results in significant contact between microorganisms and the waste components being degraded. To accelerate system start-up, introduction of microbes capable of degrading the organic constituents of the waste may be useful, although some companies have not had favorable experience with designer bugs. Many of the additives used for bioreactors are common agricultural products and plant or animal wastes. * After the desired treatment level has been reached, and depending on the constituents, liquids may be reused, transported to wastewater treatment facilities, injected, or discharged. Solids may be buried, applied to soils, used as fill, or treated further to stabilize components such as metals. * In tank-based bioreactors, operating conditions (temperature, nutrient concentration, pH, oxygen transport and mixing) can be monitored and controlled easily. Optimized biological processes ensure the best rate of biodegradation and allow for reduced space requirements relative to land-based biological treatment processes. However, capital and operation and maintenance costs for bioreactors are high relative to other forms of biological treatment. McMillen and Gray (1994) reported estimated costs for bioreactor treatment of oily cuttings wastes of approximately $500 per cubic meter. Vermiculture * Vermiculture is the process of using worms to decompose organic waste into a material capable of supplying necessary nutrients to help sustain plant growth. For several years, worms have been used to convert organic waste into organic fertilizer. Recently, the process has been tested and found successful in treating certain synthetic-based drilling wastes . Researchers in New Zealand have conducted experiments to demonstrate that worms can facilitate the rapid degradation of hydrocarbon-based drilling fluids and subsequently process the minerals in the drill cuttings. Because worm cast (manure) has important fertilizer properties, the process may provide an alternative drill cutting disposal method. In the experiments, drill cuttings were mixed with sawdust to facilitate transport, shipped to the vermiculture site, blended with undigested grass, mixed with water, and applied to worm beds. The feeding consists of applying the mixture as feedstock to windrows, which are covered to exclude light from the worm bed and protect it from becoming waterlogged. Controlled irrigation systems correct the moisture content during periods of low rainfall. The feedstock was applied to the windrows, generally once per week, at an average depth of 15 to 30 mm. The worms " work" the top of each windrow, consuming the applied material over a 5- to 7-day period. The resulting worm cast organic fertilizer is harvested and packaged for distribution and use as a beneficial fertilizer and soil conditioner. The experiments showed decreases in hydrocarbon concentration from 4, 600 mg/kg to below 100 mg/kg in less than 28 days, with less than 200 mg/kg remaining after 10 days. The specific biological mechanism responsible for these decreases is not known. Hypotheses include microbial degradation within the worm beds, favorable aerobic conditions generated by the burrowing and mixing actions of the worms, and metabolic consumption of the hydrocarbons by the worms. The results also indicated the complete degradation of the cuttings (originally 5-10 mm in diameter) and no detectable mortality among the worms. The occurrence of increased heavy metal concentrations and indications of bioaccumulation in the worm cast at higher application and feeding rates would require further study or the use of alternative weighting materials . The apparent optimal portion of cuttings in the feedstock is 30 to 50%. An important factor for success is the use of drilling fluids designed for bioremediation and vermiculture technology. Linear, paraffin-type base fluids, combined with nitrate or acetate brine phases, enable the worms to add value to the cuttings that are already relatively clean due to the specific design of the fluids . Discharge to Ocean(Off-Shore) In early offshore oil and ga development, drilling wastes were generally discharged from the platforms directly to the ocean. Until several decades ago, the oceans were perceived to be limitless dumping grounds. During the 1970s and 1980s, however, evidence mounted that some types of drilling waste discharges could have undesirable effects on local ecology, particularly in shallow water. When water-based muds (WBMs) were used, only limited environmental harm was likely to occur, but when operators employed oil-based muds (OBMs) on deeper sections of wells, the resulting cuttings piles created impaired zones beneath and adjacent to the platforms. At some North Sea locations, large piles of oil-based cuttings remain on the sea floor near the platforms. Piles of oil-based cuttings can affect the local ecosystem in three ways: by smothering organisms, by direct toxic effect of the drilling waste, and by anoxic conditions caused by microbial degradation of the organic components in the waste. Current regulatory controls minimize the impacts of permitted discharges of cuttings. Some offshore waste disposal requirements in U. S are: * No discharge of free oil (using a static sheen test) or diesel oil * Acute toxicity must have a 96-hour LC50 > 30, 000 ppm (using EPA's mysid shrimp toxicity text) * Metals concentrations in the barite added to mud must not exceed: * 1 mg/kg for mercury * 3 mg/kg for cadmium * No discharge of drilling wastes allowed within 3 miles of shore (except for Alaskan facilities in the offshore subcategory) * SBMs themselves may not be discharged * Cuttings coated with up to 6. 9% SBMs may be discharged * Ester SBMs can have up to 9. 4% SBM on cuttings * Polynuclear aromatic hydrocarbon (PAH): * Ratio of PAH mass to mass of base fluid may not exceed 1 x 10-5 * Biodegradation rate of chosen fluid shall be no slower than that for internal olefin * Base fluids are tested using the marine anaerobic closed bottle test Treatment Processes prior to Discharge After coming to the platform, drilling wastes are placed on a series of vibrating screens called shale shakers. Each successive shale shaker uses finer mesh screen, so the collected particles are smaller in size. The liquid mud passes through the screens and is sent back to mud pits on the platform to be reused. If the recycled mud contains fine particles that would interfere with drilling performance, the muds are treated using mud cleaners or centrifuges to remove very fine particles. At the end of a drilling job or at the end of a particular interval that uses a specialized mud, the bulk mud will either be returned to shore for recycling or discharged to the sea. The solid cuttings coated with a film of mud remain on top of the shale shakers and are collected at the opposite end of the shakers. If the cuttings are able to meet the discharge standards at this point, they are generally discharged. If they are unable to meet the discharge standards (particularly relevant when SBMs are being used), the cuttings must be treated further by vertical or horizontal cuttings dryers, squeeze presses, or centrifuges. The cuttings dryers recover additional mud and produce dry, powdery cuttings. Underground injection of Drilling Waste(reinjection) Several different approaches are used for injecting drilling wastes into underground formations for permanent disposal. Slurry injection technology: It involves grinding or processing solids into small particles, mixing them with water or some other liquid to make a slurry, and injecting the slurry into an underground formation at pressures high enough to fracture the rock. Types of slurry injection The two common forms of slurry injection are annular injection and injection into a disposal well. Annular injection introduces the waste slurry through the space between two casing strings (known as the annulus). At the lower end of the outermost casing string, the slurry enters the formation. The disposal well alternative involves injection to either a section of the drilled hole that is below all casing strings, or to a section of the casing that has been perforated with a series of holes at the depth of an injection formation. Many annular injection jobs are designed to receive wastes from just one well. On multi-well platforms or onshore well pads, the first well drilled may receive wastes from the second well. For each successive well, the drilling wastes are injected into previously drilled wells. In this mode, no single injection well is used for more than a few weeks or months. Other injection programs, particularly those with a dedicated disposal well, may inject into the same well for months or years. A related process involves injection into formations at pressures lower than the formation's fracture pressure (subfracture injection). In certain geological situations, formations may be able to accept waste slurries at an injection pressure below the pressure required to fracture the formation. Wastes are ground, slurried, and injected, but the injection pressures are considerably lower than in the case of slurry injection. The most notable example of this process occurs in east Texas, where the rock overlying a salt dome has become naturally fractured, allowing waste slurries to be injected at very low surface injection pressures or even under a vacuum. A commercial waste disposal company has established a series of subfracture injection wells at several locations in east Texas. These wells have served as the disposal points for a large percentage of the drilling waste that is hauled back from offshore platforms in the Gulf of Mexico for onshore disposal. Thermal treatment Technology Thermal technologies use high temperatures to reclaim or destroy hydrocarbon-contaminated material. Thermal treatment is the most efficient treatment for destroying organics, and it also reduces the volume and mobility of inorganics such as metals and salts. Additional treatment may be necessary for metals and salts, depending on the final fate of the wastes. Waste streams high in hydrocarbons (typically 10 to 40%), like oil-based mud, are good candidates for thermal treatment technology. Thermal treatment can be an interim process to reduce toxicity and volume and prepare a waste stream for further treatment or disposal (e. g., landfill, land farming, land spreading), or it can be a final treatment process resulting in inert solids, water, and recovered base fluids. Thermal treatment technology is generally set up in a fixed land-based installation, but some efforts are under way to develop mobile thermal treatment units and units that might fit on an offshore platform. Its application is not geographically limited, but large size and weight coupled with limited processing capacity have limited its use offshore. Costs for thermal treatment range from $75 to $150/ton, with labor being a large component. The volumes of oily waste from a single operator may not be high enough to justify continuous operation of a thermal treatment process, but contract operation of a centrally located facility that manages waste from multiple area operators can be a cost-effective alternative. Thermal treatment technologies can be grouped into two categories. The first group uses incineration (e. g., rotary kilns, cement kilns) to destroy hydrocarbons by heating them to very high temperatures in the presence of air. Incineration is not commonly used for drilling wastes but has greater applicability for materials like medical waste. The second group uses thermal desorption, in which heat is applied directly or indirectly to the wastes, to vaporize volatile and semivolatile components without incinerating the soil. In some thermal desorption technologies, the off-gases are combusted, and in others, such as in thermal phase separation, the gases are condensed and separated to recover heavier hydrocarbons. Thermal desorption technologies include indirect rotary kilns, hot oil processors, thermal phase separation, thermal distillation, thermal plasma volatilization, and modular thermal processors. Incineration Incineration technologies oxidize (combust) wastes at high temperatures (typically 1, 200 to 1, 500 degrees C) and convert them into less bulky materials that are nonhazardous or less hazardous than they were prior to incineration (Morillon et al. 2002). Incineration is typically used to destroy organic wastes that are highly toxic, highly flammable, resistant to biological breakdown, or pose high levels of risk to human health and the environment. Higher temperatures increase treatment efficiency. Residence time in the combustion chambers can be modified to completely break down most hydrocarbons. Generally, incineration of drilling wastes is not necessary, unless operations are located in sensitive environments and other disposal options are not available. Incinerators are generally permanent (non-mobile) units. In commercial incinerators, combustion can be optimized because residence time, temperature, and turbulence within the chamber can be controlled. Commercial incinerators are also frequently equipped with pollution control devices to remove incomplete combustion products and particulate emissions and to reduce SOx and NOx emissions. Advantages of incineration include volume reduction, complete destruction (rather than isolation), and possible resource recovery. Because energy requirements for incineration relate directly to water content, costs for incinerating drilling wastes with high water contents can be high. Rotary Kilns: Most incineration of drilling wastes occurs in rotary kilns, a mature and commercially available technology, which is durable and able to incinerate almost any waste, regardless of size or composition. A rotary kiln tumbles the waste to enhance contact with hot burner gases. Capital equipment costs for an incinerator that processes between 3 to 10 tons/hour ranges from $3 to $5 million dollars. The Canadian Crude Separator's Incineration Process (CSS) is an example of a rotary kiln process that operates under starved oxygen conditions. The unit has been permanently installed near Big Valley, Alberta, Canada. Primary chamber temperatures reach 600 to 1, 000 degrees C. Venturi section temperatures reach 1, 200 degrees C. The kiln handles 10 metric tons/day during a 24-hour operation period. The process can handle wastes with up to 10% hydrocarbons. Minimum costs to process solids with 10% hydrocarbons at the plant are $90 per metric ton. There is adequate mix material available to handle wastes arriving at the facility with hydrocarbon concentrations up to 40%, but prices increase with the percentage of hydrocarbons in the drilling waste . Cement Kilns: If available, a cement kiln can be an attractive, less expensive alternative to a rotary kiln. In cement kilns, drilling wastes with oily components can be used in a fuel-blending program to substitute for fuel that would otherwise be needed to fire the kiln. Cement kiln temperatures (1, 400 to 1, 500 degrees C) and residence times are sufficient to achieve thermal destruction of organics. Cement kilns may also have pollution control devices to minimize emissions. The ash resulting from waste combustion becomes incorporated into the cement matrix, providing aluminum, silica, clay, and other minerals typically added in the cement raw material feed stream. CONCLUSION Impacts assessed to be of high importance are the discharge of drill cuttings, the risk of offshoreand near-shore spills and the onshore disposal of waste material. Mitigation measures should be implemented to minimise these impacts and it should be possible for operations to proceed without any significant long lasting impact to the marine or coastal environment of country. A number of pro-active measures have already been instigated by Desire and Peak(an Environmental Impact Assessment organization) in planning these operations, which should be commended. In order to minimise environmental impacts it is important to ensure operations follow established procedures, training of key personnel is carried out, joint oil spill response exercises are run and contingency plans are in place to deal swiftly with any potentially polluting incidents. The production of an operations-specific addendum to this EIA(Environmental Impact Assessment) will further define the environmental management, operational controls and employee training necessary to minimize potential impacts to the environment. A variety of waste management options are available to offshore oil and gas operators in Nigeria. The Nigerian regulatory structure is mature and is reasonably well understood by major operators. Wastes are discharged to the sea when that can be done in compliance with permits and other regulatory requirements. Those wastes that cannot be discharged are injected or are brought to shore for disposal. The industry has developed an effective infrastructure for collection, transportation, and onshore disposal of wastes that are not suitable for on-site discharge or injection. REFERENCES Ayers, R. C. Jr., Sauer, T. C. Jr., Meek, R. P. and Bowers, G.. 1980. An Environmental Study to Assess the Impact of Drilling Discharges in the Mid-Atlantic. Proceedings of a

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