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AN ASSESSMENT OF EFFLUENT DISPOSAL PRACTICES IN THE PETROLEUM INDUSTRY

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ABSTRACT
The petroleum industry generates wastes in the course of extraction and refining operations. This paper summarizes the major sources of these wastes, the pollutants that are generated, the regulations that are in effect to control them and the treatment and disposal practices that are generally used throughout the country to meet these regulations. By and large, current water treatment and disposal practices in the extraction and refining industries are meeting existing effluent limitations set by the Nigerian government. However, solids handling and disposal practices may be expected to undergo some changes in order to meet the more stringent regulations that are currently being developed.
Keywords: Petroleum industry; waste, effluent, practices, regulations, water treatment and oil spills.

INTRODUCTION
The major sources of wastes generated by the oil and gas extraction industry include produced waters and drilling mud. Produced waters can contain oils, a variety of salts, solids and organic materials. Waste characteristics vary widely, but a typical produced water from Nigeria oil and gas fields is shown in Table 1. Drilling mud is formulated from a mixture of complex chemicals, organic and inorganic, plus clay and water. The chemical composition varies, depending upon specific site factors. The Federal Water Control Act amendments of 1972 established a comprehensive programme in the country to "restore and maintain the chemical, physical, biological integrity of the nation's water". The Act required the development of industry-wide uniform national effluent limitations based on the availability of technology to remove specific pollutants from the discharges.

Table 1 – Characteristics of typical produced water from Nigeria oil and gas fields

Parameter	Concentration, mg/L
Oil and Grease	200
Total Suspended Solids (TSS)	73
Total Dissolved Solids (TDS)	110,000
Chlorides	61,000
Total Organic Carbon (TOC)	400

Source: *DPR (2008)*

Federal effluent limitations establishing the best practicable control technology currently available (BPT) have been promulgated for the onshore and offshore

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subcategories of the oil and gas extraction industry. In establishing the limitations, the Nigeria Environmental Protection Agency (NEPA), which is charged with enforcement, took into account information on age and size of facility, raw materials, manufacturing processes, products produced, treatment technology available, energy requirements, and costs.

OBJECTIVE

The objective of this paper is to identify major sources of wastes, how these wastes are generated, regulated and controlled, as well as possible means of disposal in the Nigerian oil and gas industry.

REGULATIONS AND DISPOSAL PRACTICES FOR THE ONSHORE SUBCATEGORY

For the onshore subcategory, the regulations specify that there shall be no discharge of pollutants into navigable waters. This means that produced water or mud generated by onshore facilities cannot be discharged into surface water bodies. Instead, produced water is re-injected for enhanced oil recovery or injected into disposal wells. Drilling mud are land filled or placed into surface impoundments.

OFFSHORE SUBCATEGORY

Regulations

For the offshore oil and gas extraction subcategory, the regulations currently in effect are shown in Table 2.

Waste Handling Practices

To meet these regulations, most offshore oil platforms treat the produced water by equalization and gas floatation methods (Akpoturi, 2004). Equalization is used to dampen out surges in flows and loadings and enables the treatment plant to operate more effectively and with fewer maintenance problems. It usually consists of tanks or, the so-called 'Gun-barrels'. In a gas flotation unit, gas bubbles are released into the body of the waste water to be treated. The rising bubbles contact the oil droplets and rise to the surface as froth. Two types of flotation systems are presently used. The more common type is dispersed gas flotation, where rotating dispersers draw gas into the water phase through the vortex created by the rotors from gas blanket maintained above the surface. Dissolved gas flotation consists of saturating a portion of the wastewater feed with gas at a pressure of 40 to 60 psig. The wastewater is held at this pressure and then released at atmospheric pressure. The sudden reduction in pressure results in the release of microscopic air bubbles which attach themselves to oil and suspended particles and rise to form a froth layer.

Performance varies depending upon operation and maintenance practices and other factors. But generally, effluents treated by this means satisfactorily meet the regulations.

Other waste streams, including water based drilling mud, drill cuttings, deck drainage, and well treatment fluids skimmed for oil and discharge overboard. Oil muds are shipped to shore for disposal. (Ebele, 2004). The federal regulations considered minimum standards and must be adhered to by all oil and gas extraction facilities in the country which are located offshore, plus those located in lakes, wetlands, swamps, marshes, bogs, etc. However, EPA Regions and the states can and do impose more stringent regulations, should local factors demand it. For example, one region in the Gulf of Mexico has an area containing environmentally sensitive coral reefs. In this area, the discharge of drill mud is not permitted at all. And similarly in the State of California, produced water is not discharged into territorial waters, but instead is re-injected.

PETROLEUM REFINING INDUSTRY

Regulations

Process wastewater is the most significant discharge generated by petroleum refineries and may include the following sources; cooling water, cooling tower and boiler blow down, oily process, sour water, and air pollution control equipment blow-down. (Baker, 1987). Raw process wastewater quality can vary widely from plant to plant depending upon process characteristics and operating methods. With this in mind, the quality of a "typical" process wastewater is presented in Table 3. To control these pollutants, Federal regulations (FEPA) have been in effect since 1984. They are rather complex and vary according to the type of refining operations taking place, the configuration of the processing units, the quantity of feedstock being processed and the ultimate disposition of the wastewater. If the wastewater is discharged directly to a stream, the effluent requirements are more stringent than if it is being discharged into a sewer for treatment by the public treatment works. To meet Federal requirements, industry has installed large numbers of systems in the last decade.

Table 2 – Effluent BPT limitations oil and grease, mg/L

Water Source	Maximum for any 1 day	Avg. for 30 consecutive days	Residual Cl_2 minimum for any 1 day
Producer water	72	48	N/A
Deck drainage	(1)	(1)	N/A
Drilling muds	(1)	(1)	N/A
Drill cuttings	(1)	(1)	N/A
Well treatment	(1)	(1)	N/A
Sanitary			
M 10	N/A	N/A	N/A
M 9 1M (3)	N/A	N/A	N/A
Domestic	N/A	N/A	N/A

***Source:** NPDC (2009)*

N/A denotes "Not Applicable"

1) *No discharge of free oil*
2) *Minimum of 1mg/L and maintained as close to this concentration as possible.*
3) *There shall be no floating solids as a result of the discharge of these wastes. M10-Offshore facilities continuously manned by 10 or more persons. M91M-Offshore facilities continuously manned by 9 or fewer persons or intermittently manned by any number of persons.*

Table 3 – Typical refinery process wastewater characteristics

Parameter	Concentration, mg/L
Biological Oxygen Demand (BODs)	100
Chemical Oxygen Demand (COD)	390
Total Organic Carbon (TOC)	110
Total Suspended Solids (TSS)	90
Ammonia	10
Sulfide	7
Oil and Grease	90
Phenolics	11
Chromium (Total)	0.7
Chromium (Hexavalent)	0.03

Source: NPDC (2010)

Reduction of pollutants

In the United States, emphasis has shifted to techniques such as in-plant control and recycle and re-use. These techniques afford two major benefits:

1. Reduction of pollutant load to be treated by an end-of-pipe system.
2. Reduction or elimination of a pollutant before dilution in the main wastewater stream.

These options require the segregation of process waste streams and the combination of similar sources into one system. For example, sour waters can be combined from various locations within the refinery and treated as one wastewater stream. The most common treatment scheme for sour water involve sour water stripping, sour water oxidizing, or combinations of the two. Sour water stripping uses steam or boiler flue gas to extract gases from the waste water. The stripper itself is a distillation type column containing either trays or packing materials. Columns range from simple one pass systems to sophisticated refluxed columns with reboilers. The vast majority of units used in the U.S. utilize steam as the stripping medium. Sour water strippers can achieve greater than 99% removal of sulfides and greater than 95% removal of ammonia. (Encyclopedia Americana). Reduction in water usage and good housekeeping have been successful in reducing wastewater production. (Oteri, 1981). These techniques include:

1. Shutting down pump gland cooling water lines on pumps that are out of services.
2. Shutting down wash down hoses that are not in use.
3. Eliminating leaks.
4. Using dry cleaning methods.
5. Using vacuum trucks to clean oil spills.

Plant modifications have been very successful in reducing water use and pollutant loading. Some of these include:

1. Substitution of improved catalyst that require less regeneration.
2. Replacement of barometric condensers with surface condensers or air fan cooler.
3. Increased use of improved drying, sweetening, and finishing procedures to minimize spent caustics and acids, water washes, and filter solids requiring disposal.
4. Recycle of wastewater at the process units to reduce the amount of wastewater leaving the process area. Many of the streams, such as treated sour waters, cooling tower blow downs and utility blow downs are suitable for use as wash waters, make-up to cooling towers, pump gland cooling systems, and fire system water.

End of Pipe Treatment

If the process wastewater is indirectly discharged, that is, discharged to the publicly owned treatment works, treatment usually consist of separation of oil using gravity separation and dissolved air flotation. The American Petroleum Institute (API) separator is the most widely used gravity separator. It removes and recovers large quantities of reprocessable oils. The basic design is a long rectangular basin, with enough detention time for most of the oil to float to the surface and be removed. Flotation processes have been discussed previously. Control technology for those plants discharging directly to a receiving water relies heavily upon the use of pretreatment followed by biological treatment methods. Pretreatment methods include; *equalization, gravity separation of oil, and dissolved air flotation*. (Osuji, 1994)

In biological treatment, micro-organisms are used to oxidize soluble and colloidal organic materials to CO_2 and H_2O in the presence of Oxygen. (Mitchell, 1977); Methods commonly used include Oxidation Ponds, Aerated lagoons, Trickling filters, and activated sludge. (Iwugo, 1991). The Oxidation pond is practical where land is plentiful, suitable and cheap. An Oxidation pond has a large surface area and a shallow depth, usually not exceeding 2 meters (6 feet). These ponds have long detention periods from 11 to 110 days. The Aerated lagoon is a smaller, deeper oxidation pond equipped with mechanical aerators or diffused air units. The addition of oxygen enables the aerated lagoon to have a higher concentration of microbes than the oxidation pond. The retention time in aerated lagoons is usually shorter, between 3 to 10 days. In Trickling filter, the biomass is attached to the bed media, which may be rock, slag, or plastic. Most application in the petroleum industry use it to reduce the loading on the activated sludge system. The most prevalent type of biological treatment system used in this industry is the activated sludge process, in which high concentrations of microorganisms are suspended uniformly throughout a holding tank to which raw wastewaters are added. Oxygen is introduced by mechanical aerators, diffused air systems, or other means. These basic activated sludge processes consist of an aerated tank followed by a sedimentation tank. The flocculants microbial growths removed in the sedimentation tank are recycled to the aeration tank to maintain a high concentration of active microorganisms. (FEPA, 1991)

Solid Waste Handling

Solid waste can be a significant portion of the pollutant load generated by this industry and include oil skimming, tank bottom cleanings, filter clays, and treatment sledges. Current disposal practices include incineration, land farming land filling, pounding, disposal wells, and ocean disposal. Management of these residuals is currently undergoing major changes in order to meet new, stringent, regulations. These materials must now be disposed of in such a manner that ground water and air are not contaminated. Ocean disposal, deep well injection, and pounding will probably be phased out due to their potential adverse environmental impact.

OIL SPILL-DEBRIS DISPOSAL PRACTICES

A common sight at oil spill cleaning activities in piles and bins of oily solids commonly referred to as oil-spill debris. Usually, at least some oil spill debris remains to be disposed of after all recoverable oil is collected and the spill site is cleaned up. Debris solids may be composed of floatable debris such as seaweed or foam, sorbent materials such as straw or plastic foam, or sand, gravel, rocks and dirt, depending upon location of the oil spill and the clean-up method used. For example, oil spilled in a water body is generally contained by booms to facilitate removal by vacuum trucks, sorbents, or other methods. Any floating debris within the area will likely become contaminated by oil. Oil spilled on land or washed onto shore may be collected by excavating the underlying soil oil-coated vegetation. Also, sorbents such as foam pads and porous beads may be used to soak up the oil. In either case, significant volumes of solid debris are collected which must be properly stored, transported, and disposed of to minimize the potential for further adverse environmental impacts. In order to deal with these oil spills that will inevitably continue to occur in the future, it is necessary to develop debris disposal contingency plans today.

Site Selection

Proper site selection is basic to a safe oil spill debris disposal plan. Otherwise problems such as ground and surface water contamination, and adverse effect on vegetation can occur. Although many factors are important, few key considerations will be mentioned.

a) Soil conditions are of primary importance. A debris burial or land filling site should have a low permeability, fine grain soil such as clay or silt, while for land cultivating, a coarser grained soil would be more suitable to promote rapid biodegradation of oil.
b) Data on groundwater quality characteristics are important, such as depth to groundwater, direction of groundwater depth, water quality characteristics, and water use.
c) Surface topography and vegetation can influence the potential for surface and groundwater contamination and vegetative damage from oily waste.

Disposal Methods

After securing a site, it is necessary to select a method of disposal. After reclaiming as much oil as possible, the recommended disposition of the remaining oily debris in order of priority is as follows:

a) Where possible, thermally oxidize the remaining oily debris (i.e. burn, incinerate, pyrolyze). (Warren, 1971)
b) Land cultivation. Oily wastes are spread on and mixed with soils to promote aerobic microbiological degradation.
c) Land filling with refuse. Oil spill debris is incorporated into an active sanitary landfill along with municipal refuse or industrial wastes.
d) Burial. Oil spill debris is deposited into pits and trenches. The excavated soil is used as intermediate and final cover over the debris.

The method selected depends upon site specific and on the characteristics of the spill debris. Some of these factors include:

a) Size distribution of the debris solid matter
b) Biodegradability of debris constituents.
c) Oil content in the debris.

Land cultivation is best suited for debris comprised of small particles such as oiled soils. The land cultivation method entails rototilling, discing or otherwise mixing the debris with site soils. Thus, land cultivated debris should not contain particles larger than about 15 cm (6 inches) to avoid handling difficulties and ensure proper mixing. Vegetation such as seaweed, brush, or leaves that can be readily broken up and mixed with the soil can also be included in the debris intended for land cultivation.

Debris with some large, bulky items can be land cultivated if the bulky items are segregated and either cleaned or disposed-off at a sanitary landfill or a burial site.

The basic intent of land cultivation is to promote microbial degradation of the carbonaceous matter. Thus, land cultivation should not be practiced if noticeable amounts of inorganic, non-degradable items (such as plastics) are present in the debris. Degradation of oil by land cultivation proceeds best in warm climates with moderate precipitation and evaporation. Sufficient moistures is required in the oil/soil mixture to support microbial activity. Except in very dry areas, adequate moisture is usually naturally available. Land cultivation has been successfully employed in areas receiving less than 38 cm (15 inches) of precipitation per year with more than 165 cm (65 inches) of evaporation without providing additional moisture.

Virtually all types of oil spill debris can be disposed-off by land filling with refuse or burial alone. Proper site selection and preparation are needed to ensure that oil and/or water do not drain from debris.

Debris disposal by land filling or burial is well suited for any landform except flood plains and inland valley. Oil contained in debris disposed or by these methods will remain under graded for many decades. Thus, disposal sites located where flooding or washout potential is high, present a threat to water quality.

The particular disposal method selected will depend upon the specific events surrounding an oil spill. Whenever possible, the land cultivation method should be considered at the first alternative to incineration since the oil will be degraded and thus present no long term environmental problems. The land filling and burial methods at appropriate site are acceptable if properly implemented when land cultivation is not practical. (Wilson, 1981)

CONCLUSION

In conclusion, current water treatment and disposal practices in the petroleum extraction and refining industries are meeting existing effluent limitations set by the Nigerian government. Studies are currently underway to establish standards for new sources and to assess the "best available treatment technology economically achievable" (BAT) for existing sources. For these studies intensive sampling programs have been conducted to determine the presence of 129 priority pollutants. More advance treatment technology options are being examined. Preliminary indications are that more stringent regulations will not be promulgated for liquid effluents in the near future. On the other hand, solids handling and disposal practices can be expected to undergo some chances in order to meet the more stringent regulations that are currently being developed. In the future, solid and sludge waste materials will have to be disposed-off in a manner such that ground water air will not be contaminated.

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