Environmental Impact from Drilling and Production of oil Activities: Sources and Recommended Solutions

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Abstract

In petroleum industry, there are two major operations that can potentially impact the environment: Drilling and production. Both activities generate a significant volume of wastes include drill cuttings contaminated with hydrocarbons, wide variety of chemical additives, produced water and air pollutants. The potential impact depends primarily on the material, its concentration after release, and the biotic community that is exposed.

In this study, many drilling locations and production facilities have been investigated and examined for their adverse effects on the environment. Contamination with hydrocarbons, heavy metals, salts, other associated wastes and air pollution were detected at many sits.

Understanding of drilling and production wastes and how they are generated, improved operations that minimize or eliminate any environmental effects can be developed. Moreover, protection of human life, soil and water resources can be achieved through the implementation of proper waste management.

Keywords: environment, drill cuttings, air pollutants, heavy metals.

التاثير البيئي الناتج من الحفر و الانتاج للفعاليات النفطية: المصادر و الحلول المقترحة

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الخلاصة:

توجد في الصناعة النفطية عمليتان رئيسيتان واللتان تؤثران بشكل فعال على البيئة هما الحفر والانتاج. كلا الفعاليتين تنتجان حجوم مؤثرة من المخلفات والتي تشمل القطع الصخرية الملوثة بالهايدروكاربونات ومدى واسع من الاضافات الكيميائية والماء المنتج والملوثات الهوائية. ان التاثير الفعال لهذه المخلفات يعتمد بشكل رئيسي على المادة الملوثة وتركيزها.

تم في هذه الدراسة زيارة عدد من مواقع الحفر والانتاج واختبارها لملواثاتها وتاثيراتها على البيئه.ان التلوث بالهايدروكاربونات والمعادن الثقيلة والاملاح والملوثات المرافقة قد تم تشخيصها في العديد من هذه المواقع.

ان تفهم مخلفات الحفر والانتاج وكيفية توليدها ومعرفة الفعاليات المتطورة التي تقلل وتحدد التاثيرات البيئية وحماية العاملين والتربة ومصادر المياه يمكن الوصول اليها من خلال تطبيق الاستراتيجية المناسبة .

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Introduction:

The process of finding and producing of oil and gas generate a variety of wastes which can full into the general categories of drilling waste, produced water, and associated wastes. In 1992, wells drilled in the United States, yielding on the order of 300 million barrels of drilling waste [1]. Currently, Abu Dhabi Oil Company (ADOC), is producing an estimated 20000 tons of oily cuttings and about 900000 barrels of waste fluids have to be disposed off every year [2].produced water accounts for about 98% of the total waste stream in the U.S.A, with drilling and associated wastes accounting for the remaining 2% [3].

These wastes can be impact the environment and the greatest impact arises from the release of wastes into the environment in concentrations above naturally found.

Generally, contamination of soil, surface water and ground water with drilling and production activities can be related to the waste sources and as following [4-12] :

The drill cuttings contain varying amounts of hydrocarbons (oil, gas, volatile organic compounds).

1. Drilling mud and additives may contain potentially hazardous substances including a variety of metals (arsenic, cadmium, copper, lead, zinc, etc.) and various other hydrocarbons and organic compounds (e.g., methanol, benzene and toluene).
2. Drilling mud reserve pits may also contain a mixture of other additives and chemicals that are used during the drilling process which may include acids, corrosion inhibitors, bactericides, surfactants, thinners, weighting materials and lost-circulation materials.
3. Produced water which may include volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), heavy metals and naturally occurring radioactive materials (NORM).
4. Production fluids and wastes.
5. Dehydrator waste production pits. The waste water from dehydration processes may contain dissolved hydrocarbons and metals such as arsenic, barium, chromium and lead.
6. Work over/ completion fluids. Potentially toxic work over fluids includes strong acids such as hydrochloric or hydrofluoric acids, corrosion inhibitors, and painting and cleaning related wastes. Stimulation fluids are sometimes considered to be work over/ completion fluids. Toxic hazardous and carcinogenic materials can be found into stimulation fluids such as benzene, PAHs, sodium hydroxide, and variety of heavy metals (e.g., antimony, barium, mercury, silver, thallium, vanadium and zinc).

This paper examines into drilling and production of oil activities and their wastes which have adverse environmental impact. Also, it presents recommended solutions to minimize the environmental effects of oil industry. These solutions are based on field investigations and worldwide practices dealing with best waste management.

Field Observations and Sampling

Many of oil drilling sites (Basrah, Maisan and Kirkuk) and production facilities (Baghdad, Basrah, Kirkuk, Ninava and Salah Din) were investigated and contamination problems were found at more than 70% of these locations. Issues of concern included:

Ongoing discharges to surface and groundwater were documental at 50% of the sites inspected.

1. Leaks and spills were observed from equipment.
2. Waste pits were improperly designed, located, and operated.
3. Overflow from the sides of the pit due to inadequate storage volume of the pit.
4. Excessive usage of some drilling materials such as bentonite and barite. Bentonite is a very expansive material and this may create a great soil volume change and possibly damage to surface structures.
5. A number of operations at drilling and production facilities emit volatile material into the air which cause air pollution. Also, internal combustion engines used to power drilling rigs, compressors and pumps, are represent the longest source of air pollution. Dust from construction and unpaved access roads can also be observed.
6. Inefficient equipment are not properly operated and maintained. Fugitive emissions from leaking valves, flanges, and such fittings can also be noticed.

The heavy metals and other dissolved solids contents in both the water and mud (sludge) phases of thirty pits scattered around Iraq were measured. Also, thirty samples were taken from spills and leakages from equipment at many production activities and analyzed for some heavy metals concentrates.

Results and Discussion

The mean metals concentrations of all of the pits are summarized in table -1. It was found that the metals concentrations in the mud phase were almost higher than in the water phase indicating that most of the metals were bound to the organic and clay particles.

It is important to notice that the storage/disposal practices may be a source of some metals such as arsenic, benzene, fluoride and lead in the pits which are not been detected in the active mud systems as shown in table-2.

Total heavy metal concentration in sludge samples are generally high as indicated in table-3. Obviously, inefficient equipment should be replaced with newer, more efficient equipment. Important environmental features of newer equipment should be how easy they are to monitor and clean up besides its cost-effectiveness.

Many operations associated with the production of oil and gas generate wastes such as wastewater from cooling towers, water softening wastes, contaminated sediments, different lubrication oils, and site construction wastes.

The concentrations of ten major heavy metals found in waste water of many production site are listed in table -4. A number of methods are available to treat contaminated water to prepare it for reuse or disposal. The water contaminants can be either suspended or dissolved which can be removed by many methods among of them gravity separation, heater treaters, filtration, adsorption, volatilization and oxidation [13, 14, 15]. In general, the different treatment methods vary considerably in effectiveness and cost.

Not all wastes generated by drilling and production operations are intrinsically hazardous. Any suspect waste generated from a particular activity can be simply tasted using the decision tree, figure-1

This flowchart (decision tree) is presented according to general common characteristics of hazardous wastes and a list of exempt materials from Resource Conservation and Recovery Act (RCRA). A list of RCRA exempt wastes and a list of RCRA nonexempt wastes are provided [16, 17].

Clearly, a waste is considered to be characteristically hazardous if it fits any of criteria include ignitability, corrosivity, reactivity, toxicity, explosivity and others see figure-.1. Some of these characteristics are measurably by standardized testing procedures such as flammability, corrosivity and reactivity. Moreover, some of the parameters than can be used in assigning hazardous characteristics with direct and simple testing procedures like PH, flashpoint and solubility.

In general, if the generated waste is considered to be hazardous according to RCRA list, "cradle-to-grave" management and tracking of the waste to dedicated site is then required. This management must include waste storage, transportation, treatment, and disposal.

Recommended Solutions

I. Pollution Prevention through Materials Substitution Option

Minimizing the total volume and/or the toxic fraction of wastes generated by exploration and production of oil and gas can be considered the most effective way in reducing the whole environmental impact of such operations. Using less toxic materials for the various operational processes represent an important approach in waste minimization concept. A number of studies in materials substitutions have been presented [18, 19, 20, 21]. However, it is important to ensure that the substituted materials yield materials that still have acceptable properties.

Many of used materials at drilling and production sites have a significant amount of toxic components. Mud thinners (chrome lignosulfonate), lubricating compounds (mineral oil), and H_2S scavengers (Zinc oxide) are some of these toxicants materials or additives. Elimination of these toxicants through the use of low-toxicity substitutes should be done to reduce the toxicity of drilling mud system at all. For example titanium lingosulfonate has been suggested to replace chromium-lingosulfonate [22].

A variety of materials are available during drilling stage to substitute less toxic materials for more toxic, traditional materials are given in table-5 and table-6 [11, 19, 23].

Moreover, there are many alternative materials or activities that can be practiced during drilling or production operation among of them the following:

1. A variety of new water-based mud are being developed as possible alternative choose for oil-based mud.
2. Additives made from water-soluble combinations of silicon, phosphorous, aluminum and boron can replace some conventional toxic additives.

3. Disposal brushers can be wed to eliminate the need for paint thinners and solvents.
4. To reduce the emission of volatile hydrocarbons at production facilities, vapor recovery systems must be installed.
5. The generation of So_x from internal combustion engines can be minimized by using a low sulfur fuel such as natural gas.

II. Management of Drilling and Production Wastes

A number of waste management stratiges have been presented and all of them include the ways to minimize the volume and / or toxicity of wastes generated and ways to resuse recycle, treatment and disposal of wastes options [24, 25, 26, 27].

The field observations and results showed that the comprehensive environmental production plans including waste management and contingency plans, are needed to optimize the use of oil industry resources. Some of environmental audits and waste management plans are that they:

1. Minimize environmental impact or damage from different operations.
2. Minimize risks associated with facilities operations.
3. Minimize operating and personnel costs.
4. Minimize costs of treating and disposing of wastes.

Moreover, any waste management program should have the following objectives:

- Minimize the volume of waste generated.
- Reuse and treat as much as possible.
- Responsible disposal of all remaining wastes in an economical and environmentally acceptable manner.

In dealing with the best waste management plan, it appears that source reduction is the most important step to be done. If source reduction is not possible, then recycling is the next best waste management option followed by treatment to reduce waste toxicity. Following volume minimizing and recycling / treatment, the third objective is disposal of unwanted (remaining) wastes in responsible way which reflect the balance between cost and environment requirements.

Generally, application of the described three objectives to have maximum possible recovery of hydrocarbons without significant environmental impact, this will lead to minimal disposal and overall cost saving.

Table 1- Mean metal concentrations of thirty pits in Iraqi oilfields.

Metal	Phase	Mean Concentration (ppm)
Calcium	Mud Water	16000 210
Chromium	Mud Water	180 11.5
Lead	Mud Water	56.6 4.2
Magnesium	Mud Water	40.5 70.5
Manganese	Mud Water	450 5.7
Potassium	Mud Water	450 1820
Sodium	Mud Water	2100 2750
Barium	Mud Water	17800 0.8
Iron	Mud Water	25000 1.9
Zinc	Mud Water	180 7.8
Carbonate	Mud Water	210 66
Chloride	Mud Water	2700 3960
Sulfate	Mud Water	2350 315

Table 2- Pollution difference between active drilling mud and waste pit.

Toxicant	active mud system	waste pit
Arsenic	No	Yes
Benzene	No	Yes
Fluoride	No	Yes
Lead	No	Yes

Table 3- Mean heavy metal concentrations of thirty sludge samples at ten oil production plants.

Metal	Mean Concentration (ppm)
Arsenic	115
Barium	350
Cadmium	1.2
Chromium	158
Cobalt	15
Copper	77
Fluoride	32
Lead	44
Mercury	10
Nickel	205
Silver	1
Zinc	230

Table 4- Composition of wastewater at five oil production plants.

Constituent	Mean Concentration (ppm)
Aluminum	1.2
Calcium	40.5
Chloride	2450
Copper	1.0
Fluoride	5.4
Iron	44
Magnesium	1.3
Manganese	1.5
Potassium	115
Sodium	22500
Sulfate	33100
Zinc	6.6

Table 5- Substitute Materials for Drilling Fluid Additives.

Material	Use	Substitute Material
Chrome lignosulfonate/lignite/ dichromate/Sulfomethylated tannin	Deflocculant	Polyacrylate and/or polyacrylamide polymers.
Sodium chromate	Corrosion control	Sulfides, phonates, and amines.
Zinc chromate	H2s control	No chromium H2S scavengers
Pentachrochlorophenol/Paraformaldahyde/ Arsenic	Biocides	Isothiazoline, carbamates, amines, and gluteraldehydes.
Barite	Mud densifier	Chose barite from sources low Cd,Hg and Pb.
Diesl oil	Drilling fluid lubricants	Mineral oil or lubra-beads
Lead-based pipe dope	Pipe thread sealant/ lubricants	Unleaded pipe dope such as lithium-based grease with microsphere ceramic balls potassium acetate or potassium carbonate.
Potassium chloride	Shale stability	Potassium acetate or potassium carbonate.

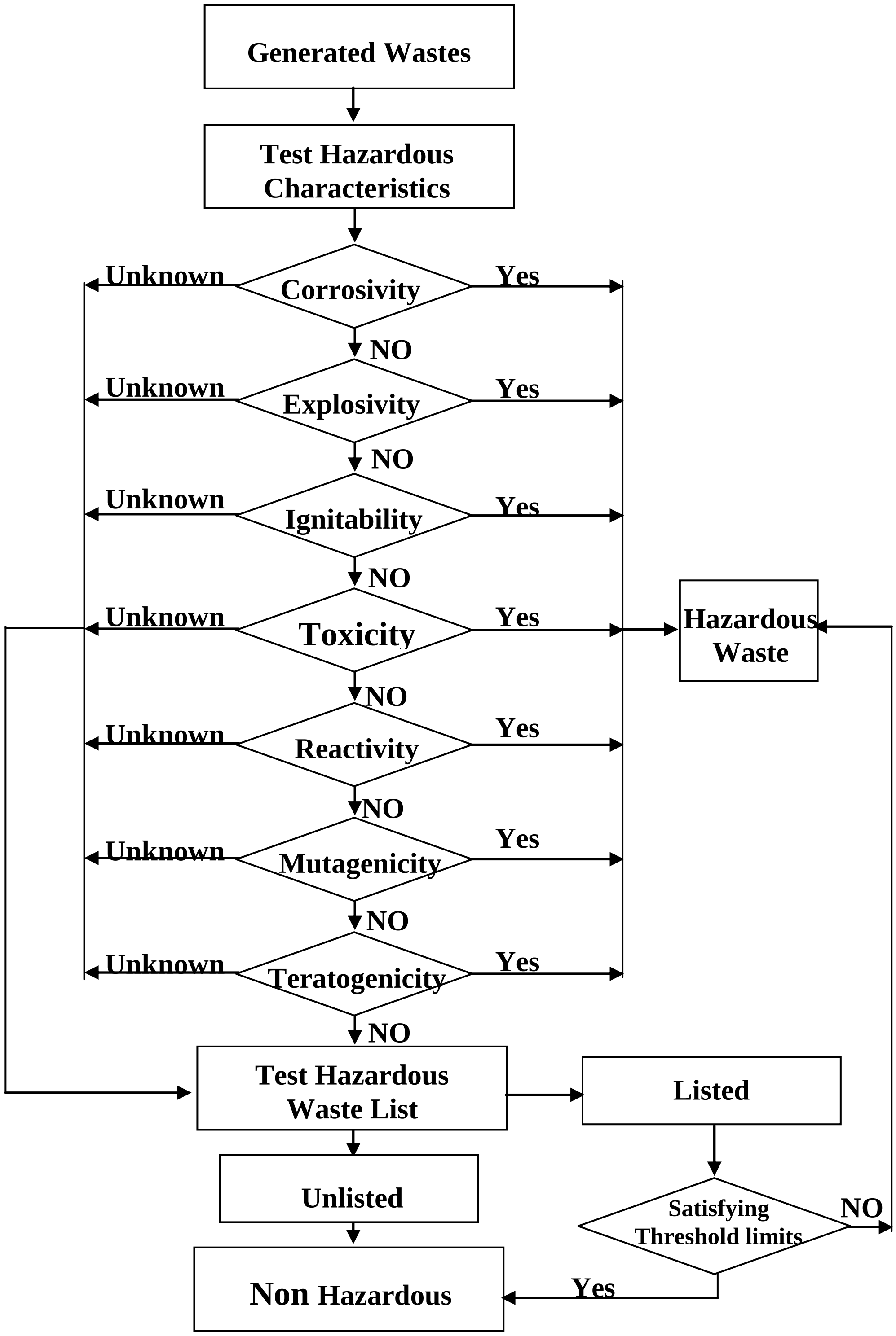

Figure 1- Flowchart to identify hazardous wastes from drilling and production activities.

Conclusions:

This paper presents a complete solutions adopted to handle the generated waste streams and eliminate the potential hazards. However, if the oil industry complies with present regulations, the environment with not noticeably affected by the operation of the oil industry. For example, much can be done to reduce the effluent quantity and quality by improving the performance of equipment, so that it will be easier and more beneficial to comply with the requirement.

The most important step that must be done by the operators, is the commitment in conservation and recycling during all stages of oil field operations.
Based on the study review, the following suggestions can be made:

1. The effective waste management plan must identify the materials and wastes at a particular site and list the best option to manage, treat, and dispose of those wastes and taken into consideration the environmental audit and its requirements.
2. For pits containing high salt or hydrocarbons levels, environmental demands require the use of an impermeable pit liner to prevent leaching to the surrounding.
3. A comprehensive site evaluation may be required before the optimum remediation process can be selected and properly implemented.
4. Discharge of pollutants must be kept to minimum levels, and existing facilities should be upgraded and improved with respect to their effect on the environment.
5. Desorption technology is recommend to be a part of the complete drilling waste management solution. It is field-proven, commercially viable and suitable for using globally. It is not only answer the environmental issue but it has the ability to turn waste into profit.

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