

THE E&P FORUM

# EXPLORATION AND PRODUCTION (E&P) WASTE MANAGEMENT GUIDELINES

Report No. 2.58/196  
September 1993



*E&P Forum*  
*Exploration & Production (E&P)*  
*Waste Management Guidelines*  
Report No. 2.58/196  
September 1993

E&P Forum, 25–28 Old Burlington Street, London W1X 1LB  
Telephone: 44-(0)71-437 6291 Fax: 44-(0)71-434 3721

#### Authors

These guidelines have been prepared for the E&P Forum by their Environmental Quality Committee through their Waste Management Guidelines Task Force.

Ms C. K. Owens	Exxon, Chairperson
Mr D. R. Rycroft	Phillips
Mr M. T. Stephenson	Texaco
Mr G. Norris	Amerada Hess
Mr J. A. Johnson	Conoco
Mr L. W. Crame	Amoco
Mr C. Inglesfield	SIPM
Mr A. Grieg	Shell Expro

#### The E&P Forum

The Oil Industry International Exploration and Production Forum (E&P Forum) is the international association of oil companies and petroleum industry organisations formed in 1974. It was established to represent its members' interests at the International Maritime Organisation and other specialist agencies of the United Nations, governmental and other international bodies concerned with regulating the exploration and production of oil and gas. While maintaining this activity, the Forum now concerns itself with all aspects of E&P operations, with particular emphasis on safety of personnel and protection of the environment, and seeks to establish industry positions with regard to such matters.

At present the Forum has 48 members made up of 33 oil companies and 15 national oil industry associations, operating in 52 different countries.

The work of the Forum covers:

- monitoring the activities of relevant global and regional international organisations;
- developing industry positions on issues;
- advancing the positions on issues under consideration, drawing on the collective expertise of its members; and
- disseminating information on good practice through the development of industry guidelines, codes of practice, check lists etc.

#### Disclaimer

Whilst every effort has been made to ensure the accuracy of the information contained in this publication, neither E&P Forum nor any of its members will assume liability for any use made thereof.

#### Acknowledgments

Design and layout: Words and Publications, Oxford

# EXPLORATION AND PRODUCTION (E&P) WASTE MANAGEMENT GUIDELINES

## CONTENTS

INTRODUCTION	2	Surface Discharge	14
Scope	2	Injection	14
Background	2	Biotreatment Methods	16
Resources Included in this Document	2	<i>Landfarming</i>	16
		<i>Landspreading</i>	17
		<i>Composting</i>	18
		<i>Biological Treatment in Tanks</i>	18
		<i>Biological Treatment—Package Units</i>	19
PRINCIPLES OF WASTE MANAGEMENT	4	Thermal Treatment Methods	19
Waste Management Hierarchy	4	<i>Incineration</i>	19
Area-Specific Waste Management Plans	6	<i>Cement Kilns—Fuel Blending</i>	20
		<i>Open Burning</i>	20
		<i>Thermal Desorption Systems</i>	20
AN OVERVIEW OF THE OIL EXPLORATION AND PRODUCTION PROCESS	8	Solidification, Stabilisation and Encapsulation	21
Seismic Identification of Potential Hydrocarbon Reserves	8	Landfill	21
Exploratory Drilling	9	Burial	21
Construction	10	Pit Management	22
Development and Production	10	Solvent Extraction	22
Maintenance	10		
Decommissioning and Reclamation	11	APPENDICES	
		1. References	24
WASTE MANAGEMENT METHODS	12	2. Glossary of Oil Industry Terms	26
Waste Management Methods	12	3. Waste Management Planning Worksheet	30
<i>Source Reduction Methods</i>	12	4. Summary of Wastes Generated by E&P Activities	32
<i>Reuse</i>	13	5. Specific Waste Information	35
<i>Recycling/Recovery</i>	13	6. Waste Management Options—Summary Tables	42
<i>Treatment</i>	13		
<i>Responsible Disposal</i>	13		

## INTRODUCTION

### Scope

These guidelines have been prepared for those oil and gas exploration and production (E&P) companies who require information on the range of waste management options available for wastes generated by their activities. Sections of the document provide:

- a general description of waste management principles
- an identification and overview of E&P activities and associated wastes, and
- options for waste reduction, recycling, treatment and responsible disposal.

Operators should be able to use these guidelines to develop a waste management programme appropriate to their activities and to the ecological sensitivity of the operating location. However, not all measures discussed in these guidelines will necessarily be appropriate for implementation in all geographic areas or under all conditions. E&P Forum guideline documents on operations within rain forest, mangrove and arctic environments provide additional information and considerations for these specific areas. Specific requirements and standards for petroleum operators should be determined by agreement between the operating company and the authorities of a host country.

### Background

Effective and responsible waste handling and disposal are key elements of an organisation's environmental management system. Exploration and Production (E&P) waste as defined for this document will be any material, solid, liquid or mixture that is surplus to requirements. There is increasing international concern that wastes be properly managed in order to minimise their potential to cause harm to health or the environment. Moreover, efficient management of wastes can reduce operating costs and potential liabilities. Characteristics of concern include flammability, reactivity, corrosivity, longevity in the environment and human, animal, or plant toxicity.

This document is designed as an information source. It is not intended to replace an operator's responsibility to ensure adequate and effective handling and disposal of generated wastes as required within a host country's regulatory requirements.

Disposal options in some areas may be restricted by lack of established waste management facilities and infrastructure. In these cases, the oil and gas operator may find it necessary to construct and manage the necessary facilities. Although this approach may be expensive in the short term, it can often minimise long-term liabilities.

### Resources Included in this Document

In addition to the discussions on waste management options included in this document, a number of appendices are provided to clarify or provide examples of some topics presented in the text. These appendices are as follows:

- Appendix 1 provides a list of references either used during preparation of this document or providing supplementary information on various issues presented.
- Appendix 2 is a glossary of oil industry terms encountered in this document.

- Appendix 3 contains a form for creating an inventory of wastes generated during E&P activities.
- Appendix 4 provides tabulation of common types of wastes generated during E&P activities, the main sources of these wastes, constituents of these wastes that may adversely impact the environment when present, and identification of the operations which may generate a specific waste stream.
- Appendix 5 includes summary sheets on a variety of common E&P wastes. These sheets discuss the characteristics of the waste streams and some waste management options that may be appropriate.
- Appendix 6 provides a table of common types of wastes generated during E&P activities and a summary of possible waste management options.

# PRINCIPLES OF WASTE MANAGEMENT

The principles of waste management include the incorporation of a hierarchy of waste management practices in the development of waste management plans. Specific waste management practices may be tailored to waste and site characteristics as well as to availability of reuse, recycle, treatment and disposal facilities.

Creating an inventory to identify and track waste streams, and record the costs associated with management of those streams, can help provide a baseline for identification of opportunities to improve practices. An accurate inventory of waste management practices recording the types of wastes, methods of treatment or disposal, and location of final disposal will not only be a valuable tool for waste minimisation programmes, but also be a source of data in the event of any question of liability for contamination, and site remediation. Appendix 3 contains a sample waste inventory sheet to aid in this process.

## Waste Management Hierarchy

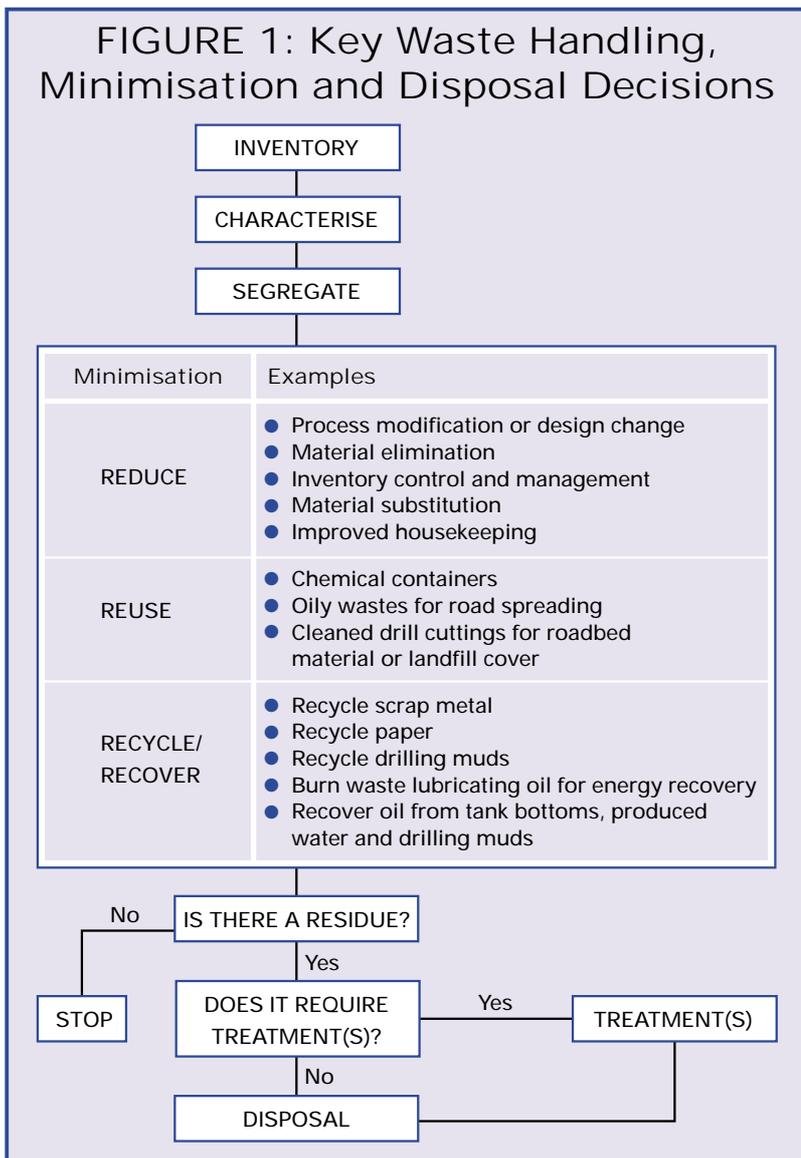
Proper management of wastes begins with pollution prevention. Pollution prevention refers to the elimination, change or reduction of operating practices which result in discharges to land, air or water. This principle should be incorporated into the design and management of E&P facilities and the planning of associated activities. If elimination of a waste is not possible, then minimising the amount of waste generated should be investigated. Responsible waste management may be accomplished through hierarchical application of the practices of source reduction, reuse, recycling, recovery, treatment and responsible disposal. Elements of these practices are shown below:

- **Source Reduction**—the generation of less waste through more efficient practices such as:
  - material elimination
  - inventory control and management
  - material substitution
  - process modification
  - improved housekeeping
- **Reuse**—the use of materials or products that are reusable in their original form such as
  - chemical containers
  - oily wastes for road construction and stabilisation
  - burning waste oil for energy
- **Recycling/Recovery**—the conversion of wastes into usable materials and/or extraction of energy or materials from wastes. Examples include:
  - recycling scrap metal
  - recycling drilling muds
  - using cleaned drill cuttings for road construction material
  - recovering oil from tank bottoms and produced water
- **Treatment**—the destruction, detoxification and/or neutralisation of residues through processes such as:
  - biological methods—composting, tank based degradation
  - thermal methods—incineration, thermal desorption
  - chemical methods—neutralisation, stabilisation
  - physical methods—filtration, centrifugation

- **Responsible Disposal**—depositing wastes on land or in water using methods appropriate for a given situation. Disposal methods include:
  - landfilling
  - burial
  - surface discharge
  - landspreading or landfarming
  - underground injection

The flow diagram shown in Figure 1 displays how these waste management practices may be applied. Specific methodologies which apply these principles are presented in the section on Waste Management Methods. The role of temporary and permanent storage of wastes in the management process is not addressed in Figure 1.

The potential ecological sensitivity of the location of operations is key to the selection of an appropriate management practice for a specific waste. This may require information on geology, hydrology, climate and biological communities. Environmental Impact Assessment documents can be a useful resource.



## Area-Specific Waste Management Plans

An area-specific waste management plan directly relates the choice of waste handling and disposal options to the ecological sensitivities, regulatory requirements and available facilities/infrastructure of the geographical area involved. The plan should be written from the field perspective and provide specific guidance for handling each waste stream. In developing such a plan, an E&P facility or company could follow the 10 general steps outlined below.

● ***Step 1: Management Approval***

Management approval and support should be obtained. Key personnel or other resources and scheduling issues should be resolved such that management is aware of the timing and scope of the plan. The overall goal(s) of the waste management plan should be established with measurable objectives stated for each goal.

● ***Step 2: Area Definition***

The waste management plan is area-specific and should include a description of the geographical area and specific business activities addressed. The primary consideration in selecting an area is homogeneity from both an ecological and a regulatory standpoint.

● ***Step 3: Waste Identification***

Operations personnel should identify all the wastes generated within the area defined for each E&P activity (i.e., production, drilling, completion/workover, natural gas plants). A brief description for each waste (sources, percent oil and/or saltwater content and approximate volume) will assist in further management steps. Appendix 3 contains an inventory form which may facilitate this effort.

● ***Step 4: Regulatory Analysis***

Review international, regional and host country laws and regulations to determine the types of wastes for which management practices should be highlighted. Waste types for which the regulations do not adequately define management requirements should then be identified.

● ***Step 5: Waste Categorisation***

The physical, chemical and toxicological properties of each waste should be identified. This information may be found via Material Safety Data Sheets (MSDS), manufacturers information, process knowledge, historic information or lab analyses. A system to categorise waste streams according to their health and environmental hazards can then be developed.

● ***Step 6: Evaluation of Waste Management and Disposal Options***

A list of the potential waste management option(s) for each waste should be compiled using the section on Waste Management Methods and Appendices 5 and 6 as a guide, and available options should be identified. The acceptability of each option for the different ecological domains in the plan area can then be determined.

Evaluation should include: environmental considerations; location; engineering limitations; regulatory restrictions; operating feasibility; economics; potential long-term liability; etc. The list of the acceptable waste

management options and the desirability of each should be reviewed by appropriate operations personnel and management.

In the event that intractable waste streams (such as those containing polychlorinated biphenyls (PCBs) or radioactivity) are identified, the management method of permanent storage in specialised storage facilities may be the only available option for reducing environmental risk.

#### ● *Step 7: Waste Minimisation*

Opportunities for reduction or elimination of waste, volume or toxicity reduction, recycling and reclaiming, or treatment should be reviewed when evaluating management options. When a potential waste minimisation practice is identified, a pilot test may be desired for evaluation. Revision of the waste management plan should be made to reflect any minimisation practices implemented.

#### ● *Step 8: Selection of Preferred Waste Management Practice(s)*

From the evaluation of waste management and disposal options, selection of the best practice for that operation and location can be made. A life-cycle analysis assessing the risks associated with storage, treatment, transport and disposal of a particular waste stream may provide additional insight into which management practices should be given preferred status. Through these processes, operations personnel may justify several of the current waste management practices and/or identify new or modified practices.

#### ● *Step 9: Implementation of an Area Waste Management Plan*

Compile all the preferred waste management and disposal options for each waste found in a given operating area into one comprehensive, area-specific waste management plan.

The recommended waste management practices should be summarised in concise documents for use at the field level. Descriptions should include only the wastes generated by the operations in the specific area or within an operator's responsibility. Each waste description should indicate the chosen waste management and disposal practice.

#### ● *Step 10: Plan Review and Update*

Effective waste management is an ongoing process. The plan should be reviewed whenever new waste management practices or options are identified. A procedure to review and update the waste management plan should be established, and practices modified to reflect changing technologies, needs, or regulations.

Area waste management planning, implementation and review offers reassurance with regard to :

- protection of the environment and ongoing compliance with regulatory requirements
- ongoing training of field personnel
- appropriateness of the plan itself, and
- minimisation of the volume and toxicity of the wastes

The waste management plan should be a living 'evergreen' document which requires periodic review and revision.

## AN OVERVIEW OF THE OIL AND GAS EXPLORATION AND PRODUCTION PROCESS

In order to appreciate the potential impacts of oil and gas development upon the environment, one must understand the activities involved. This chapter briefly describes the oil and gas exploration and production process. The guidance in this document addresses only the waste management aspects of these activities. In order to fully understand the range of environmental impacts associated with these activities, reference should be made to other guidelines and documents listed in Appendix 1.

In the following discussions, common wastes are listed for each activity. A more detailed listing of wastes associated with various E&P activities is provided in Appendix 4.

### Seismic Identification of Potential Hydrocarbon Reserves

In the first stage of the search for hydrocarbon-bearing rock formations, geological maps are reviewed to identify major sedimentary basins. Aerial photography may be used to identify promising landscape formations such as faults or anticlines. More detailed information is then assembled using a field geological assessment, followed by one or more of three main survey methods: magnetic, gravimetric and seismic. Of these a seismic survey is the most common and is often the first field activity undertaken.

#### *Description*

Seismic surveys require the generation of acoustic waves at specified points along a relatively straight survey line. The acoustic waves are reflected by changes in the subsurface geological strata. The reflections are detected by many sensors arranged along several kilometres of the survey line (over several square kilometres in the case of a 3D survey) and recorded. Line preparation may involve cutting vegetation prior to surveying the data point and sensor locations. As recording progresses along the survey line onshore, the sensors are moved to new positions along the survey line by crews using vehicles or helicopters. The data are processed by computer to map the underlying strata and help define the size and shape of any geologic structure worthy of further investigation.

Several methods are available to generate the acoustic waves; these include the use of shot holes, Vibroseis techniques, or air or water guns. The shot hole method involves the detonation of small explosive charges placed in small diameter holes drilled to a depth generally ranging from one to thirty metres. In the Vibroseis method, a group of three to five heavy vehicles (vibrators) lower and then vibrate a heavy pad at specific points on the surface. Air or water guns create the acoustic waves used for the survey by releasing compressed air or water to create loud sonic vibrations.

Because land seismic activities are highly mobile, base camps are temporary in nature. In order to protect surface water bodies, sanitary pits and biodegradable garbage pits should be at least 100 metres from the water, if possible. Non-biodegradable, flammable wastes may be burned and the ashes buried with the non-flammable wastes. This burial should be at least one metre deep. If the area water table is high, burial criteria should be reconsidered.

### *Common Wastes*

*The primary wastes from seismic operations include domestic waste, sewage, explosive wastes, lines, cables and vehicle (including ship) maintenance wastes.*

Once a promising geological structure has been identified, the only way to confirm the presence of hydrocarbons and the thickness and internal pressure of a reservoir is to drill exploratory boreholes ('wells').

### Exploratory Drilling

The location of a drill site is dependent upon the characteristics of the underlying geological formations. Modern drilling techniques allow some flexibility in choice of location, allowing consideration of both environmental protection and logistical needs, while still reaching reservoir development objectives.

### *Description*

A site is constructed to accommodate drilling operations and support services. Offshore, a drilling barge, semi-submersible drilling rig or a drilling ship is used to provide all of the functions associated with drilling the well. On land, a typical one-hole exploration site occupies between 5000 and 20,000 square metres. The type of site construction is dependent on seasonal constraints and geography. Drilling rigs and support equipment are normally divided into modules to facilitate transportation. Depending on access roads, site location and module size and weight, drilling rigs may be moved by land, air or water transportation.

Once on site, the rig and a self-contained support camp are assembled. Typical modules include a derrick, drilling mud handling equipment, power generators and cementing equipment. The camp provides workforce accommodation, canteen facilities, communications, vehicle maintenance and parking areas, a helipad (for remote sites), fuel handling and storage areas, and provision for collection, treatment and disposal of wastes.

Once drilling commences, drilling fluid or mud is continuously circulated down the drill pipe and back to the surface equipment to balance underground hydrostatic pressure, cool and lubricate the bit and flush out rock cuttings. The risk of uncontrolled flow from the reservoir to the surface is further reduced by using blowout preventers, a series of hydraulically actuated steel rams that can close around the drill string or casing to quickly seal off a well. Steel casing is run into completed sections of the borehole and cemented into place. The casing and cement provide structural support to maintain the integrity of the borehole, isolate underground formations, and protect usable underground sources of water. Where a hydrocarbon formation is found, initial well tests are conducted to establish flow rates, formation pressure, and the physical and chemical characteristics of the oil and gas.

### *Common Wastes*

*The primary wastes from exploratory drilling operations include drilling muds and cuttings; cementing wastes; well completion, workover and stimulation fluids; and production testing wastes. Other wastes include excess drilling chemicals and containers, construction materials (pallets, wood, etc.), process water, fuel storage containers, power unit and transport maintenance wastes, scrap metal and domestic and sewage wastes.*

## Construction

Construction of some infrastructure and facilities will be required to support activities.

**Description**

Construction of facilities such as roads, camps, canals and pipelines may be required both before and during the development and production process. The construction process may use a wide variety of materials, equipment and methods. The facilities required for a specific activity will depend on the activity and its geographic location.

**Common Wastes**

*The primary wastes from construction activities include excess construction materials, used lubricating oils, paints, solvents, sewage and domestic wastes.*

## Development and Production

Development and production operations are conducted to extract the oil and gas from the reservoir.

**Description**

A small reservoir may be developed using one or more of the exploratory wells. Further development of the reservoir may require additional wells. A production facility may be required to separate, store and transport produced fluids. The size and type of the installations needed for storing, separating and transporting oil, gas and water will depend on the nature and location of the reservoir, the volume and nature of produced fluids and the export option selected. These options include transport by road, waterway, pipeline or some combination of these.

Routine operations on a producing well include monitoring, safety and security inspections and periodic downhole servicing using a wire line unit or a workover rig. In some areas, a self-contained base camp may be established to support routine operations. The base camp provides workforce accommodation, communications, vehicle maintenance and parking, fuel handling and storage, and provision for collection, treatment and disposal of wastes.

The operator will be able to extract only a portion of the oil present using natural pressure and simple pumping. A range of enhanced recovery methods, including waterflood, gas injection and methods employing chemicals, gases or heat may be used to increase the efficiency of oil production.

**Common Wastes**

*In addition to the wastes listed under Exploratory Drilling, Construction and Maintenance, the main wastes from development and production operations include discharged produced water, flare and vent gas, production chemicals, workover wastes (e.g. brines) and tank or pit bottoms.*

## Maintenance

Maintenance of vehicles, mechanical equipment and infrastructure may be required for operations of extended duration.

**Description**

Maintenance activities are common to all phases of the exploration and production process. During seismic and construction activities, maintenance is essentially limited to vehicle repair and inspection. Exploratory drilling maintenance activities include vehicle and drilling rig repair and

inspection. Maintenance activities during development and production include repair and inspection of vehicles, generators, drilling rigs, workover rigs, fluid process equipment and infrastructure.

*Common Wastes*

*The primary wastes associated with maintenance activities include batteries, used lubricants, filters, hoses, tyres, paints, solvents, contaminated soil, coolant and antifreeze chemicals, used parts and scrap metals.*

Oil and gas installations are decommissioned at the end of their commercial life.

Decommissioning and Reclamation

**Description**

Decommissioning generally involves permanently plugging and abandoning all wells, and may include removal of buildings and equipment, transfer of buildings and roads to local communities or host government entities, implementation of measures to encourage site re-vegetation and site monitoring.

*Common Wastes*

*The primary wastes from decommissioning and reclamation include construction materials, insulating materials, plant equipment, sludges and contaminated soil.*

## WASTE MANAGEMENT METHODS

As in any aspect of environmental management, there are some general 4 good practices that should be employed. These good practices not only protect health and the environment but also help protect E&P operators from potential long-term liabilities associated with waste disposal. Waste management methods should be selected based upon the hierarchy presented on page 4.

Some of the treatment and disposal methods that may be used for E&P wastes are described on page 14 onwards. The omission of a particular management option from the list discussed here is not meant to imply that it can not be effective. Certainly, as research on waste management progresses, additional options will be identified.

An important aspect of a waste management programme is the need to segregate waste materials according to their general physical and chemical characteristics. Apart from safety concerns, an initial waste characterisation will help determine which waste streams are similar and may be combined to simplify storage, treatment, recycling, and/or disposal, and which streams should remain segregated. Failure to recognise the need for waste segregation may result in the creation of a waste mixture incompatible with the desired recycling or disposal option and result in the need for extensive lab analysis and higher waste disposal costs.

### *Source Reduction Methods*

Source reduction means eliminating or decreasing, to the extent practical, the volume or relative toxicity of wastes generated by using alternate materials, processes or procedures.

*Volume*—Opportunities to achieve significant waste volume reductions for some E&P wastes are limited because their volumes are primarily a function of activity level and age or state of reservoir depletion. For example, the proportion of discharged produced water typically increases as the reservoir is depleted. Also, the volume of drilling muds generated is generally a function of the number of wells drilled and their depth. Nevertheless, opportunities exist for source reduction and efforts should be made to exploit them. For example, use of proper solids control equipment can reduce the volume of mud discharged.

Process modification may be possible through more effective use of mechanical components, such as more effective drill bits, rather than chemical additions. Gravel packs and screens may significantly reduce the volume of formation solids/sludge produced. Improved controls will help minimise mud changes, engine oil changes and solvent usage.

*Toxicity*—Substitution of products that result in the generation of less toxic wastes should be investigated. For example, biocides, corrosion inhibitors, coagulants, cleaners, solvents, dispersants, emulsion breakers, scale inhibitors, viscosifiers and weighting agents should be selected with potential environmental impacts and disposal needs in mind. Some examples are the selection of mud and additives that do not contain significant levels of biologically available heavy metals or toxic compounds, and the use of mineral oils in place of diesel oil for stuck drill pipe.

Other efforts should include: efficient planning so that all commercial chemical products are used on the site or returned unused to vendors;

consideration of bulk chemical purchases to eliminate drums; and use of drains and sumps to collect and segregate spills.

### ***Reuse***

After all waste reduction options have been considered, the next step is to evaluate reuse of the waste material. The reuse may be in the same, alternative, or downgraded service, or the return of unused materials for re-issue or reuse in other industries. Examples include: use of drill cutting waste for brick manufacture and roadbed material, use of vent gas for fuel, use of produced water or process water as wash water, and return of oil based drilling mud to the vendor for reprocessing and re-issue.

Wastes such as tank bottoms, emulsions, heavy hydrocarbons, and hydrocarbon bearing soil may be used for road oil, road mix, or asphalt. These wastes should be analysed to ensure they are not flammable and have a mixed density and metals content consistent with road oils or mixes. Application of hydrocarbon wastes to roads should be at loading rates that minimise the possibility of surface run-off.

### ***Recycling/Recovery***

After all waste reduction and reuse options have been considered, the next step is to evaluate recycling and recovery of the waste material either in-process, on-site, or with outside contractors. When available, the recycling of drilling muds in mud plants should be considered.

There are potential benefits in the sale of recovered hydrocarbons. All hydrocarbon wastes should be returned to the production stream where possible. Recovery of hydrocarbons from tank bottoms and separator sludges via centrifuging or filtering can be accomplished at on-site production facilities or off-site commercial facilities.

When recycling scrap metal, monitoring should be considered to ensure that metal with NORM (LSA) scale is not sent to the recycling facility along with uncontaminated materials.

### ***Treatment***

After source reduction, reuse, recycling and recovery opportunities have been examined, potential treatment steps to minimise waste volumes or toxicity should be considered.

Treatment methods include: biological methods (e.g. landspreading, composting, tank based reactors), thermal methods (e.g. thermal desorption and detoxification), chemical methods (e.g. precipitation, extraction, neutralisation) and physical methods (e.g. gravity separation, filtration, centrifugation).

Examples of treatment methods include: biodegradation of oily wastes in a pit by tillage and addition of nutrients (fertilizer); and stabilisation of mud pit wastes by adjusting the pH to chemically stabilise and reduce potential toxicity and mobility of inorganic compounds.

### ***Responsible Disposal***

Finally, after all practical source reduction, reuse, recycling, recovery and treatment options have been considered and incorporated, responsible disposal options for the residue should be determined. The following criteria should be examined when evaluating waste disposal options. This information will help in determining the long-term fate of a waste and its constituents and should be applied to both on-site and off-site disposal facilities.

*General Area Overview*—Review the relevant laws and regulations of the area and the availability of off-site disposal facilities.

*General Site Overview*—Review the area-wide topographical and geological features. Also, review current and likely future activities around the disposal site.

*Hydrological Evaluation*—Review hydrogeologic data to identify the location, size and direction of flow for existing surface water bodies and aquifers characterised as fresh or usable.

*Area Rainfall or Net Precipitation Conditions*—Obtain historical rainfall distribution data to establish moisture requirements for landspreading, determine how quickly reserve pits will dry, predict net evaporation rates, evaluate pit overflow potential, etc.

*Soil Conditions and Loading Considerations*—Determine soil conditions prior to making decisions on loading for landspreading and whether or not pits will require liners. For example, in high clay content and permafrost areas, liners may not be necessary for reserve pits. In other areas with sandy soils and shallow usable groundwater, liners or even tanks may be more appropriate.

*Drainage Areas*—Determine natural or existing drainage patterns and identify drainage devices needed to control water flow into, onto, or from facility systems.

*Environmental Sensitivity*—Conduct a site evaluation to identify environmentally-sensitive features such as wetlands, urban areas, historical or archaeological sites, protected habitats, or presence of endangered species.

*Air Quality*—Give consideration to potential air quality impact of waste management facilities.

### Surface Discharge

Surface discharge is one disposal option for aqueous waste streams. Factors to consider include the sensitivity and capacity of the potential receiving environment, the concentration of potentially harmful components in the waste and the volume of the discharge stream. The capacity of the receiving environment to naturally absorb pollutants is a function of the dilution potential and volume of the receiving water body. In this regard, the discharge of a high volume, saline waste stream into a small creek may not be appropriate while discharge of the same waste stream into a large water body may be acceptable.

### Injection

Injection refers to the pumping of waste fluids or slurries down a well into suitable underground formations for disposal. Injection may refer to the one time pumping of wastes down an annulus or to specially monitored wells which may receive fluids for many years. Disposal wells are designed to provide an avenue, or wellbore, to transport liquids into underground reservoirs in a manner that will not adversely affect the environment. The target formation for disposal should be geologically and mechanically isolated from usable sources of water. This formation will not contain commercial quantities of oil and gas.

Many liquid wastes may be managed using an injection well. The highest volume fluid that may be handled by E&P disposal injection wells is pro-

duced water. Other wastes suitable for injection may include: process water, blowdown liquids, cooling water, dehydration and sweetening waste liquids and waste drilling fluids.

As a management practice, injection (other than annular injection) is an expensive process requiring extensive planning and control. In most cases, an injection well and system will require considerable E&P activity in a particular area to justify the investment in drilling a well or converting an existing producing wellbore to injection service. Other considerations include:

- The injection volume required—the volumes of produced water and other liquid or solid wastes to be injected should be determined. This will indicate the number of wells to be drilled and connected to the injection system.
- The nature of the formation—the formation to receive the waste should have sufficient permeability, porosity, thickness and areal extent, and low reservoir pressure in order to handle the forecast volume and injection rate on a long-term basis. The geology of some areas may be unsuitable for injection due to the presence of extensive geological faults resulting in reservoirs small in areal extent, formations that seal poorly around a well, formations that tend to fracture to the surface, or formations with insufficient permeability or close proximity to aquifers.
- The mechanism for transportation of the waste to the injection well—a gathering system and pumping facilities may be necessary or the transport could be via tank truck or other means.
- Pre-treatment(s) necessary before injection—treatments necessary before injecting produced water into a salt water disposal well may include oil removal, coagulation and sedimentation to remove suspended solids, filtration, aeration, oxygen exclusion and removal, and bacteria and mineral scale treatment. Solid wastes may have to be ground and slurried prior to annular injection.

#### ***Annular Injection***

Annular injection is a disposal method where pumpable wastes (usually reserve pit fluids) are injected into the surface casing or production casing annulus (or other casing or casing annulus). This practice should be managed so that the wastes do not enter underground sources of water.

Annular injection is usually a 'one-time' option and is not suitable for continuous disposal. The reasons for this include the mechanical inability to clean the disposal zone of accumulated debris and the threat of corrosion of the production casing string and the interior of the surface pipe or other casing. If the surface pipe is breached by corrosion during long term injection service, the injected fluids may enter usable water sources.

#### ***Downhole Injection***

Downhole disposal of waste muds and cuttings, both oil and water based, from both onshore and offshore wells may be suitable. The principle and practice is the same as for annular injection, described above, except that the liquid or slurried mud waste is pumped downhole. Due to the large particle sizes, drill cuttings cannot be injected downhole directly as they will quickly plug the receiving formation. The cuttings must be broken up into small particles and slurried with mud or water before they can be injected. Systems typically include a 'grinding' machine, pumps, recirculating lines, tanks and shakers or desanders to remove large solids.

## Biotreatment Methods

Many organic compounds present in E&P wastes may be biodegraded to carbon dioxide and water using natural biological processes. However, natural biodegradation of contaminants tends to be rate limited due to limitations on the biological processes. These limitations may be overcome by optimising the biological conditions. The most important factors for control of biological degradation of hydrocarbons are:

- an adequate supply of hydrocarbon degrading bacteria
- availability of sufficient oxygen (and mixing) for cell metabolism
- availability and balance of nutrients and micro-nutrients necessary for optimum bacterial metabolism
- moisture control
- temperature and pH
- salinity

The concentration and type of compounds to be degraded may have a significant impact on the biodegradation process. Some compounds may be readily degraded at low concentrations but inhibit degradation at higher concentrations (for example, some hydrocarbon compounds may be toxic to degrading organisms at high concentrations). Other compounds may be degraded very slowly by biological processes, require an acclimatisation period or require co-metabolites for degradation. In general, the composition of an organic waste should be examined to determine the feasibility of reaching desired treatment levels. High levels of asphaltenes and/or polynuclear aromatic hydrocarbons (PAH) in a waste may make biological treatment an unlikely option for rapid removal of the hydrocarbon fraction. Conversely, high concentrations of alkanes in a waste would make it a good candidate for biological treatment. In general, the biodegradability of petroleum hydrocarbon fractions follows the relationship: saturates > aromatics > polars > asphaltenes.

Hydrocarbon degrading microbes are ubiquitous in the environment. However, they may be present in very low concentrations in some waste streams, environments exposed to extreme conditions, or materials contaminated by extremely high concentrations of certain compounds. If microbial populations are low in a waste, native soils may often provide the microbial inocula necessary for biodegradation (as described in the landfarming, landspreading and composting sections below). If for some reason soil microbes are inadequate or the waste conditions are particularly harsh, strains of bacteria adapted to metabolise hydrocarbons under the desired conditions may be added. Waste biological sludges from refinery waste water treatment systems, if available, are an excellent source of hydrocarbon degrading bacteria.

Of the biological treatments described below, landfarming and landspreading may be considered disposal options as well as treatment. Composting processes and bioreactors generally convert the waste into a less harmful product for subsequent use or disposal. Rates of biodegradation are highest for bioreactors and composting, and lowest for the less favourable biological conditions generally found in landfarming and landspreading.

#### *Landfarming*

Landfarming systems have been used for the treatment of oily petroleum industry wastes for many years. The landfarming process involves the controlled and repeated application of waste on a soil surface in order to biodegrade hydrocarbon constituents by using microorganisms naturally present in the soil. The landfarming area is periodically tilled to provide the necessary mixing and oxygen transfer. Active landfarming may include addition of water, nutrients and other materials to enhance the biodegra-

gradation process in the waste/soil mixture, and to prevent the development of conditions that might promote leaching and mobilisation of inorganic contaminants. The conditions under which degradation takes place are typically aerobic. Volatilisation and dilution are two other important mechanisms for reduction of degradation products in land applications of waste. Landfarming should not be confused with landfilling or burial, in which the waste is deposited in man-made or natural excavations for an indefinite period of time. The conditions under which landfilled and buried wastes are stored are usually anaerobic, which typically results in much slower degradation.

Care should be taken to avoid landfarming of material which contains significant levels of biologically available heavy metals, persistent toxic compounds, or low specific activity (LSA) scale. At inappropriate loadings, these may accumulate in the soil to a level that renders the land unfit for further use. A site monitoring programme is recommended to ensure such accumulation is not occurring.

Considerations for the application of landfarming should also include the site topography and hydrology, and the physical and chemical composition of the waste and resultant waste/soil mixture. Waste application rates should be controlled to minimise the possibility of run-off. When a facility is properly designed, operated, and monitored, landfarming is usually a relatively cost-effective and simple technique. Landfarms may require government permits or approval and, depending on soil conditions, may require a liner and/or groundwater monitoring wells. Moisture control to minimise dust (particulates) may also be necessary during extended dry conditions.

### ***Landspreading***

The treatment processes involved in landspreading are similar to those in landfarming. However, landspreading refers to the one-time application of liquid or solid waste to a site. Landspreading may be an appropriate technique to reduce the organic content of a waste. As in landfarming, inorganic compounds and metals are not only diluted into the soil, but may be incorporated into the matrix through chelation, exchange reactions, covalent bonding etc., or may become less soluble through oxidation, precipitation and pH effects.

In landspreading as in landfarming, aerobic biodegradation of hydrocarbons may be enhanced by nutrient addition to the waste/soil mixture and by periodic tillage of the mixture (to increase aeration). For E&P wastes, salts and hydrocarbons are most frequently the components which limit the application rate of a waste on a site. Hydrocarbon concentrations may be monitored after landspreading to measure progress and determine whether biodegradation processes should be enhanced.

In general, there is little regulatory guidance concerning landspreading practices. This is primarily due to the fact that landspreading sites only receive a single application of waste. This practice reduces the potential for the accumulation of waste components in the soil, as might be the case in landfarming sites that receive multiple applications of wastes. Construction of a containment system (liners) or monitoring of leachates from the site is seldom required for landspreading sites. However, site topography and hydrology, and the physical and chemical composition of the waste and resultant waste/soil mixture, should still be assessed and waste application rates controlled to minimise the possibility of run-off.

Landspreading is most effectively used as a disposal method for drilling fluids and cuttings with low levels of hydrocarbons and salts, but it may also be useful for other E&P wastes with these same characteristics. Characterisation of a waste, and treatability studies can be used to determine whether landspreading may be effectively implemented.

### *Composting*

Composting is a solid phase biological treatment technique similar to land treatment. Biodegradation rates are enhanced by improving porosity, aeration, moisture content, and operating temperature. It may be possible for compost mixtures with up to ten percent hydrocarbon to be reduced to less than one percent in four to eight weeks.

Characteristics of composting are:

- Waste is mixed with bulking agents (e.g. wood chips, straw, rice hulls or husks) to provide increased porosity and aeration potential. Care should be taken to ensure the bulking agent provides sufficient porosity to allow aeration even at high moisture levels.
- Manure or agricultural wastes may be added to increase the water holding capacity of the waste/media mixture and to provide trace nutrients.
- Nitrogen and phosphorous based fertilisers, as well as trace minerals (e.g. Fe, Cu, Mo, Mn, Zn, B, Co, Ni) may be added to enhance microbial activity.
- Mixtures of the waste, soil (to provide indigenous bacteria) and other additives, may be placed in piles small enough (less than 3 feet deep) to be tilled for aeration, or placed in containers or on platforms designed to allow forcing of air through the composting mixture. Composting in closed containers allows for control of volatiles.
- The compost mixture is maintained near 40–60 percent water by weight to provide optimal moisture conditions for biodegradation.
- Compost systems are characterised by elevated temperatures (30–70 °C) within the compost mixture. The elevated temperature increases microbial metabolism, but should be closely monitored to ensure temperatures do not exceed 70 °C (may cause cell death). Temperature may be controlled by tilling the soil pile or by forced aeration.

The degradation of organic compounds using composting techniques can be much more efficient than landspreading or landfarming techniques. In addition, treated waste is contained within the composting facility and its properties may be readily monitored. Composted wastes that meet health-based criteria may be reused as soil conditioners, landfill cover, clean fill, etc.

### *Biological Treatment in Tanks*

The same aerobic biological reaction that occurs during landfarming or composting processes may be accomplished at an accelerated rate using an open or closed vessel or impoundment. The process is typically operated as a batch or semi-continuous process. Nutrients are added to a slurry of water and waste, and oxygen (for aerobic degradation) is provided by air sparging and/or intensive mechanical mixing of the reactor contents. The mechanical mixing also provides a high degree of contact between microorganisms and the waste component to be biodegraded. A source of microbes capable of degrading the organic constituents of the waste may also be required to accelerate start-up of the system.

Operating conditions (temperature, pH, oxygen transport and mixing, and nutrient concentrations) may be easily monitored and controlled in tank

based bioreactor systems. This control makes optimisation of biological processes possible, hence ensuring the best rate of biodegradation. Bioreactors generally require less space than land-based biological treatment processes. A disadvantage of bioreactors is that the maintenance and capital investment required is high relative to other forms of biological treatment.

After reaching the desired level of treatment, the disposal method for residual reactor contents will be dictated by the concentrations of the remaining components. Depending on the constituents, liquids may be transported to waste water treatment facilities, injected or discharged. After dewatering, solids may be buried, applied to soils, used as fill, or further treated to stabilise components such as metals.

#### ***Biological Treatment—Package Units***

Another variation of the optimised aerobic biological waste treatment system is an activated sludge process commercially available in self-contained package units for the treatment of sanitary wastes. The system typically includes an aeration tank with an aerator system, a clarifier tank with sludge recycle and a chlorination system for the final effluent. The process is operated continuously with an influent loading rate set to the feeding rate of the microorganisms to allow the biodegradation of the organic constituents. Following the manufacturer's recommendations for operation is suggested.

Although commercially available package units are highly efficient, they must be protected from biological upsets. Care must be taken to prevent the inadvertent dumping of cleaning chemicals, solvents, used oils and strong acids, caustics or detergents to the sanitary sewer collection system.

There are a variety of waste treatment techniques based upon the application of heat to waste materials. The resulting products from these techniques will depend on the amount of heat employed. Low temperature treatments may allow for recovery of hydrocarbons and water from wastes, whereas the use of high temperature technologies may destroy organic compounds via combustion.

#### Thermal Treatment Methods

##### ***Incineration***

Incineration uses combustion to convert wastes into less bulky materials. Incineration can refer to the practice of open burning of wastes in pits, although the degree of combustion achieved in commercial incinerators will be difficult to achieve in open burning. This is because commercial incinerators can control the residence time, temperature and turbulence within the incineration chamber to optimise combustion. These incinerators are often equipped with air pollution control devices to remove incomplete combustion products, remove particulate emissions, and reduce  $\text{SO}_x$  and  $\text{NO}_x$  emissions. There are many types of incinerators, and many air pollution control mechanisms.

Incinerators are usually used to destroy organic wastes which pose high levels of risk to health and the environment. As a rule, incineration of most E&P wastes is not necessary. However, if operations are located in a sensitive environment and other disposal options are not available, then incineration may be the best way to manage oily wastes from E&P operations.

Because of its durability and ability to incinerate almost any waste, regardless of particle size or composition, the type of incinerator best suited for

many E&P wastes is the rotary kiln. A rotating kiln tumbles the waste to provide extensive contact with hot burner gases. Depending on the size and complexity of an operation, smaller incinerators can also be effective.

Disposal of solids remaining after incineration should be managed properly. When organic components of the waste are incinerated, metals concentrations in the remaining solids will increase. An operator should ensure that incinerator ashes resulting from the treatment of its wastes are properly handled and disposed. Stabilisation may be required to prevent release of harmful leachates into the environment.

#### ***Cement Kilns—Fuels Blending***

The use of a cement kiln, when available, is usually an attractive and less expensive alternative to incineration of E&P oily wastes. Oily waste may go into a fuel blending programme to replace fuel otherwise needed to fire the kiln.

The retention time and temperature (typically 1,400 to 1,500 °C) within a cement kiln are adequate to achieve thermal destruction of organics. Cement kilns may also have pollution control devices to minimise air emissions from the process. The ash from wastes combusted in the kiln will become incorporated into the cement matrix. These ashes may provide a desirable source of aluminium, silica, clay and other minerals that are typically added in the cement raw material feed stream.

#### ***Open Burning***

Open burning is typically used to dispose of camp refuse, construction material, and hydrocarbon containing materials with properties or in areas that make recycling, recovery, or transport unsuitable. When these conditions exist and regulations permit burning, burning should be conducted in approved areas during daytime hours and should not cause a nuisance. The possible effects of emissions of particulates and products of incomplete combustion should be considered, and combustion methods that minimise emissions should be employed, when available.

#### ***Thermal Desorption Systems***

A thermal desorption system is a non-oxidising process using heat to desorb oil from oily wastes. Most thermal systems burn fuel to provide heat to volatilise the oil, but there are some systems that use electric or electromagnetic energy for heat. Thermal desorption systems are generally of two types: low temperature systems and high temperature systems. The working temperature of low-temperature systems is usually 250 to 350 °C, while high temperature systems may employ temperatures up to 520 °C. Low temperature systems may be sufficient to treat wastes with light oils. High temperature systems will be able to achieve lower final oil contents for wastes containing heavier oils.

Thermal desorption of waste streams will produce various secondary waste streams: solids, water condensate, oil condensate, and possibly an air stream from the condenser. Each of these streams may require analysis to determine its characteristics so that the best recycle/disposal option can be chosen. This is important if the original waste had high salts or metals levels, or if there are no wastewater treatment facilities on site, since additional treatment may be required to reduce the potential for environmental impact from these streams. In the case of air emissions, analysis may suggest the need for air control measures to capture certain constituents.

Solidification, stabilisation and encapsulation are often discussed together as they may be jointly achieved by some processes. In general, these processes produce dry solids (either as a monolith or a dry granular solid similar to coarse soil). Wastes treated by these technologies are stored and not destroyed. However, the concentrations or mobilities of constituents of concern in the treated waste may be different from those in the original waste.

### Solidification, Stabilisation and Encapsulation

Cement-based and pozzolanic (e.g. flyash) processes, as well as chemical stabilisation processes, have been applied in the oil industry to solidify and/or stabilise wastes. These processes are especially effective for stabilisation of metals in the wastes because, at the high pH of the cement mixture, most metal compounds are converted into non-biologically available insoluble metal hydroxides. However, high concentrations of organic compounds, salts and bentonite have been shown to interfere with the curing process, and therefore limit the application of this treatment technique. Hydrocarbons and salts do not interact with the cement matrix and are physically rather than chemically bound within the matrix.

Landfills are generally specially constructed and monitored facilities designed to accommodate burial of large volumes of wastes. However, some landfills may be little more than open dumps. A landfill may be constructed in a manner that makes it an appropriate disposal site for certain toxic wastes. A key consideration in the operation of a landfill site is the need to ensure long-term containment. Design considerations for a landfill should, therefore, include:

### Landfill

- An impermeable lining to contain the landfill contents. Liners may be constructed of clay, plastic sheeting and/or multi-layer linings with integrated drainage systems.
- Monitoring boreholes or leachate collection systems to provide a means for regular inspection of the effectiveness of the containment.
- Special provisions for disposal of liquid wastes, or prohibition of liquids disposal. If disposal of liquids is permitted, the conditions should be controlled to prevent leaching. The landfill design should include arrangements for the collection and treatment of leachate.

The operator should keep in mind that all landfills may not be constructed to the same standards, and that industrial wastes should only be disposed of in sites with the proper design criteria and proper monitoring and maintenance programmes. Landfilled materials should not be capable of reacting to generate excess heat or noxious gases. Special systems may need to be installed to collect generated methane. The operator should remember that landfilled wastes are not destroyed, but are actually in long-term storage. Disposal sites should be operated either by the waste generator who will maintain responsibility for its own wastes or by a properly managed disposal facility.

Due to its simplicity, burial of wastes in small pits at drilling and production sites has been a popular means of waste disposal in the past. However, with current awareness of pollutant migration pathways, the risks associated with burial of wastes should be carefully considered. In general, wastes with high oil, salt, or biologically available metal content, industrial chemicals, and other materials with harmful components that could migrate from the pit to contaminate usable water resources should not be buried. Burial may be the best method of disposal for inert unrecyclable materials. If a pit's contents contain concentrations of constituents only

### Burial

slightly elevated above levels regulated for disposal, then burial provides a simple mechanism to reduce concentrations in the waste, via dilution with soil, as it is being disposed. This may often be the case for water based muds and cuttings. In dilution burial, the pit contents are mixed with soils from the pit and surrounding areas until the pit contents meet specifications for burial, then the pit is covered and the surface graded.

Burial is a logical choice for wastes that have been stabilised, since migration of the constituents of the waste will be retarded by the stabilisation process. However, if there is a reason for extra caution at a particular site (either because of the constituents in the original waste, or because of the hydrogeologic characteristics of the site) then additional barriers to migration such as barrier walls around the pit, liners around the pit contents, or a cap to prevent vertical migration, could also be installed. Alternatively, and if available, the waste could be sent to a properly managed facility designed to handle that type of waste.

Consideration of factors such as the depth to groundwater, and the type of soil surrounding the pit should be made before wastes are buried. This ensures proper protection of soil and water resources.

When burial and/or pit closure is complete, the area should be graded to prevent water accumulation, and revegetated with native species to reduce potential for erosion and promote full recovery of the area's ecosystem.

### Pit Management

The use of pits, earthen or lined, is an integral part of E&P waste management operations. Historically, on-site pits have been used for the management of drilling solids, evaporation and storage of produced water, management of workover/completion fluids and for emergency containment of produced fluids.

In general, pits should be as small as possible and be strategically located to prevent spillage of waste materials onto the drilling or production site. Pits should be lined unless site characteristics ensure that there will be no significant threat to water resources. In areas where it may be necessary to construct pits adjacent to water bodies or on sloping terrain, special engineering precautions should be taken to ensure the integrity of the pit. Free hydrocarbons should be removed from pits and returned to the production process for recovery as soon as possible, and precautions should be taken to prevent pit disposal of chemicals, refuse, debris or any other materials which were originally not intended to be placed in pits. These materials can alter the nature of the bulk fluids in the pit and make disposal more difficult.

Although pits are an accepted component of E&P operations, they could represent an environmental liability if managed improperly. Pits should be for temporary use, and should not be used for disposal of oil. Pits should be closed as soon as practicable and their closure should follow the required or generally accepted practices of the region.

### Solvent Extraction

Solvent extraction uses solvents to extract oil from oily solids or sludges. Solvents used for extraction include carbon dioxide, propane, hexane, triethylamine, methylene chloride and certain proprietary solvent mixtures. An elaborate solvent recovery system is generally employed in order to reuse the solvent.

A properly operated solvent extraction system will recover and recycle virtually all solvent used for extraction, and allow oil to be recovered. A closed loop system for the vapour phases generated should ensure that there are no direct air emissions from the process. Safety will be a consideration for systems which use high temperatures, high pressures or volatile solvents.

Disposal options for wastewater separated from the solids, and the treated solids, will depend on the constituents of the treated streams. Extracted water may be injected or require treatment prior to discharge. Treated solids may be heat treated to remove residual solvents prior to disposal. Solids with significant biologically available metal contents may be stabilised to prevent migration after disposal.

## APPENDIX 1

## References

A Review of Solidification/Stabilisation Technology, Wiles, C. C., *Journal of Hazardous Materials*, 14 (1987), 5–21.

An Evaluation of Organic Materials that Interfere with Stabilisation/Solidification Processes, in *Petroleum Contaminated Soils, Volume I, Remediation Techniques, Environmental Fate, Risk Assessment*. Cullinane, M. J., Jr. and Bricka, R. M., (Kostecki, P. T. and Calabrese, E. J., eds.) Lewis Publishers, Chelsea, Michigan, 1989, 127–136.

*API Environmental Guidance Document: Onshore Solid Waste Management in Exploration and Production Operations*, API document 811–10850, January 1989.

*Combustion and Incineration Processes: Applications in Environmental Engineering*, Niessen, W. R., Marcel Dekker, Inc., New York, New York, 1978.

Composting of Chemical Industrial Wastes Prior to Land Application, in *Land Treatment of Hazardous Waste*, Willson, G. B., Sikora, L. J. and Parr, J. F., (Parr, J. F., Marsh, P. B. and Kla, J. M., eds.), Noyes Data Corp., Park Ridge, N. J., 1983.

*Chemical Usage in Offshore Oil and Gas Production Systems*, Hudgins, C. M., Report to API, 1989.

*E&P Forum Guidelines for the Planning of Downhole Injection Programmes for Oil Based Mud Wastes and Associated Cuttings from Offshore Wells*, Report No. 2.56/187, October 1993.

*E&P Forum Oil Industry Operating Guideline for Tropical Rainforests*, Report No. 2.49/170, April 1991.

*Exploration and Production Industry Associated Waste Report*, API document 0300-004-008, May 1988.

*Handbook for Stabilisation/ Solidification of Hazardous Wastes*, Cullinane, M. J., Jones, L. W. and Malone, P. G., EPA/540/2-86/001, June 1986, (NTIS no. PB87-116745).

*Handbook of Hazardous Waste Incineration*, Brunner, C. R., TAB Professional and Reference Books, Blue Ridge Summit, Pennsylvania, 1989.

*Oil and Gas Exploration and Production Operations in Mangrove Areas—Guidelines for Environmental Protection*, World Conservation Union (IUCN)/E&P Forum joint publication, 1993, ISBN 2–8317–0187–2, E&P Forum Report No. 2.54/184.

*Oil and Gas Industry Exploration and Production Wastes*, API document 471-01-09, July 1987.

*Oil and Gas Exploration and Production in Arctic and Sub-Arctic Onshore Regions—Guidelines for Environmental Protection*, World Conservation Union (IUCN)/E&P Forum joint publication, 1993, ISBN 2–8317–0188–0, E&P Forum Report No. 2.55/185.

Oilfield Environmental Control Technology: A Synopsis. Wojtanowicz, A. K. *Journal of Petroleum Technology*, 166–173, February 1993.

*Onsite Treatment: Hydrocarbon Contaminated Soil*, Western States Petroleum Association, 1990.

*Production Waste Management Handbook for the Alberta Petroleum Industry*, Canadian Petroleum Association, December 1990.

Solid-Waste Disposal: Deep Well Injection, Smith, M. E., *Chemical Engineering*, April 9, 1979, 107–112.

The Effect of Volatile Organic Compounds on the Ability of Solidification/Stabilisation Technologies to Attenuate Mobile Pollutants, Kyles, J. H., Malinowski, K. C., Leithner, J. S. and Stanczyk, T. F., in *Proceedings of the National Conference on Hazardous Wastes and Hazardous Materials*, HMCRI (1987), 152–157.

## APPENDIX 2

## Glossary of Oil Industry Terms

<i>acidising</i>	The treatment of a well by injection with a solution of acid (hydrochloric, hydrofluoric, acetic, formic, citric) to maintain or increase permeability of a rock stratum by dissolving pore blockage due to fine particles from the reservoir stratum, precipitated materials or corrosion products, so improving productivity or injectivity (see 'injection') of a well.
<i>annulus</i>	The space surrounding a cylindrical object within a cylinder; the space around a pipe in a wellbore, the outer wall of which may be the wall of either the borehole or the casing, sometimes termed the annular space.
<i>aquifers</i>	Rock strata which contain, and are permeable to, water. The water may be fresh or saline, and either potable or non-potable.
<i>BTEX</i>	Benzene, Toluene, Ethylbenzene and ortho-, meta-, and para-Xylene.
<i>biologically available</i>	Also bio-available. Substances which are present in a form which can be taken up by plants or animals and which may be incorporated into their tissues.
<i>biocides</i>	Materials which can be added to muds or reinjected produced water for the purpose of prevention or limitation of growth of bacteria in the mud or in the oil-reservoir rock.
<i>biodegradable</i>	Susceptible to breakdown, into simpler—often soluble and/or gaseous—compounds, by microorganisms in the soil, water and atmosphere. Biodegradation often converts toxic organic compounds into non- or less-toxic substances.
<i>BOD (biochemical oxygen demand)</i>	Measure of the quantity of dissolved oxygen (expressed in parts per million) used in the decomposition of organic matter by biochemical action.
<i>brine</i>	Salt water. May be produced water or mixed solutions most commonly containing sodium, potassium, or calcium chloride salts. When added to drilling muds, brine has three functions: 1. minimise reaction between mud and soluble salts in the strata being drilled; 2. increase mud weight; 3. increase mud viscosity.
<i>CFC</i>	Chlorofluorocarbon.
<i>consolidation materials</i>	Chemical mixture pumped down a well to stabilise the formation structure or minimise water production.
<i>completion fluid</i>	Chemical mixture present in the well during the placement of production tubing and perforation of the well (may be a drilling fluid, or specialised brine).

<i>cuttings</i>	The fragments of rock dislodged by the drilling bit and brought to the surface in the drilling mud.
<i>development well</i>	Well drilled in a formation for the purpose of producing oil and gas. Also called a production well.
<i>drilling chemicals</i>	Chemicals used in the formulation and maintenance of drilling muds.
<i>drilling fluids</i>	Specialised fluid made up of a mixture of clays, water (and sometimes oil) and chemicals, which is pumped down a well during drilling operations to cool and lubricate the system, remove cuttings and control pressure.
<i>drilling muds</i>	See <i>drilling fluids</i> .
<i>drilling rig</i>	See <i>rig</i> .
<i>decommissioning</i>	The act of taking an operating site out of service. This may include the final plugging of wells and the removal of surface structures.
<i>descalers</i>	Substances added to prevent build-up of, and to a lesser extent remove, solids such as calcium carbonates and sulphates deposited on the drill pipe and casing. Pitting corrosion of metal can occur under scale deposits.
<i>downhole</i>	Down a well or borehole.
<i>Environmental Impact Assessment</i>	A formal, written, technical evaluation of potential effects on the environment (atmosphere, water, land, plants and animals) of a particular event or activity.
<i>effluents</i>	Liquid waste materials discharged from operations.
<i>encapsulation</i>	The enclosure of wastes by a non-permeable substance. Waste constituents are not chemically altered, but their transport will be impeded by the encapsulating matrix.
<i>exploration</i>	The search for reservoirs of oil and gas, which includes aerial and geophysical surveys, geological studies, core testing and drilling of wells.
<i>exploration drilling</i>	Drilling carried out to determine whether hydrocarbons are present in a particular area or geological structure or to learn more about subsurface structures.
<i>fracturing</i>	The process of cracking open, by applying hydraulic pressure, the rock formation around a well bore to increase productivity or injectivity.
<i>fracturing fluid</i>	Heavy, viscous fluid pumped down a well under high pressure to fracture the target formation in order to enhance fluid flow.

<i>flaring</i>	Controlled disposal of surplus combustible vapours by igniting them in the atmosphere.
<i>gas processing</i>	The separation of constituents from natural gas for the purpose of making saleable products and also for improving the quality of the natural gas.
<i>HCFC</i>	Hydrochlorofluorocarbon.
<i>H<sub>2</sub>S (hydrogen sulphide)</i>	A pungent, corrosive, toxic gas occurring naturally in some oil and gas reservoirs (and elsewhere), generated by the metabolism of certain types of bacteria.
<i>hydrotest</i>	The checking of the integrity of a container (e.g. a tank or pipe) by filling it with water under pressure and testing for any loss of pressure.
<i>injection well</i>	A well used to inject gas or water into an oil/gas reservoir rock to maintain reservoir pressure during the secondary recovery process. Also a well used to inject treated wastes into selected formations for disposal.
<i>MSDS/SDS</i>	Material Safety Data Sheet used by chemical suppliers to summarise properties of products, including health, safety and environmental aspects.
<i>NORM</i>	Naturally Occurring Radioactive Materials. Low Specific Activity (LSA) scale is one example of a NORM waste.
<i>PAH</i>	Polynuclear Aromatic Hydrocarbon.
<i>produced water</i>	Water originating from the natural oil reservoir, that is separated from the oil and gas in the production facility.
<i>production</i>	That phase of petroleum operations that deals with bringing the reservoir fluids to the surface and separating them, and with storing, gauging, and otherwise preparing the product for the pipeline.
<i>production treating chemicals</i>	Chemicals used to enhance or assist the production process or protect equipment.
<i>reclamation</i>	The activities undertaken to restore a site to a predetermined land-use.
<i>recoverable reserves</i>	That proportion of the oil/gas in a reservoir that can be removed using currently available techniques.
<i>rig</i>	A collective term used to describe the equipment, including the vessel or structure on which the equipment is installed, required to drill a well, the most visible component being the mast or derrick.

<i>road oil</i>	Oil used for dust control or road base stabilisation, generally spread on the road and incorporated by tilling and compaction.
<i>scrubbing</i>	Purifying gas by treatment with a water or chemical wash.
<i>seismic survey</i>	A survey conducted to map the depths and contours of rock strata by timing the reflections of sound waves released from the surface or from down a borehole (shot hole).
<i>shot hole</i>	A borehole in which an explosive is placed for blasting in use as the energy source for seismic survey.
<i>solidification</i>	The addition of materials (sawdust, adsorbent polymers, etc.) to a waste to change its physical state and improve handling and weight-bearing characteristics.
<i>stabilisation</i>	The chemical conversion or encapsulation of waste to create a composite matrix that resists leaching.
<i>stimulation fluids</i>	Chemical mixture pumped down a well to stimulate or enhance the production of hydrocarbons from that well.
<i>vent gases</i>	Those gases which are released, unburnt to the atmosphere. Venting may be deliberate (for operational reasons) or accidental.
<i>Vibroseis</i>	A commercial heavy, vehicle-mounted, vibration system used onshore for the generation of shock (sound) waves into the ground during seismic surveys.
<i>VOC</i>	Volatile Organic Compounds.
<i>water injection</i>	The pumping of water into the reservoir rock to maintain the reservoir pressure.
<i>well completion</i>	The activities and methods used to prepare a well for the production of oil and gas. This may include establishment of a flow line between reservoir and surface.
<i>well servicing</i>	The maintenance work performed on an oil or gas well to improve or maintain the production from a formation already producing.
<i>wellbore</i>	The hole made by drilling or boring; may have a casing in it or it may be open, or a portion may be cased.
<i>workover</i>	A process by which a completed production well is subsequently re-entered and any necessary cleaning, repair and maintenance work done.

## APPENDIX 3

### Waste Management Planning Worksheet

The following form is an example of a worksheet which could be used when developing area waste management plans. Completion of such forms requires input from personnel who are familiar with both operational and technical aspects of E&P activities. To ensure consistency, procedures used to classify wastes should be defined before completing a worksheet. These classifications should agree with any local regulatory agency definitions.

The space for specifying the operation/equipment generating the waste can be used to document the incident or event causing waste generation. Examples include periodic tank cleaning, spills and leaks. Examination of these records may then assist in identifying process or procedure modifications to reduce or eliminate wastes. Completion of other table items is outlined in the legend below.

*To determine how you want to manage your waste, list the wastes you generate, their sources (e.g. operation or equipment), volumes (e.g. bbls, m<sup>3</sup> or tons), frequency of generation (e.g. per day, per week, per year), known hazardous characteristics (e.g. pH <2), and classification (degree of hazard). Describe the current waste disposal practices (e.g. onsite or off-site, disposal method used and name of disposal facility). List all the alternative waste management options (e.g. minimisation, road and land spreading, burial, injection) and record any special constraints that affect your options. Taking everything into consideration, choose the preferred management option.*



## APPENDIX 4

Summary of Wastes  
Generated by E&P Activities

The following table summarises the primary types of waste streams encountered during E&P operations. The main sources of these streams are provided for clarification. The constituents that may be of environmental concern are also summarised for each waste. The inclusion of a constituent in this column does not necessarily indicate that the constituent is always present, or that if the constituent is present that it will be of high enough concentration to warrant concern. The last column of the table indicates which of the individual E&P activities may generate the indicated waste stream.

WASTE STREAM	MAIN SOURCES	POSSIBLE ENVIRONMENTALLY SIGNIFICANT CONSTITUENTS	TYPE OF OPERATION
Absorbents	Spill clean up	Hydrocarbons, production chemicals, solvents	A C D M P S
Air Emissions	Vent gases Flare Gases Blowdown from bulk chemicals	NO <sub>x</sub> , SO <sub>x</sub> , H <sub>2</sub> S, CO <sub>x</sub> , VOC, hydrocarbons, carbon, particulates, PAH's, BTEX	D P
Air Emissions	Engine exhausts	CO <sub>x</sub> , SO <sub>x</sub> , NO <sub>x</sub> , VOC, PAHs, formaldehyde, carbon particulates	A C D M P S
Air Emissions	Fugitive gases	VOC, BTEX	A C D M P
Ballast water	Tankers with non-segregated ballast	Hydrocarbons	P
Boiler/cooling tower blow down	Steam generation facilities and cooling towers	Scale inhibitors, biocides, corrosion inhibitors, heavy metals, solids	D M
Cement	Cement slurries Cement mix water Cement returns	Heavy metals, thinners, viscosifiers, pH, salts	D P
Consolidation materials	Carrier fluids Epoxy resins	Hydrocarbons Excess chemicals	P
Contaminated soil	Spill/leaks	Hydrocarbons, heavy metals, salts, treating chemicals	A C D M P S
Contaminated drainage water	Rainwater run-off Rig wash Process water Wash water	Inorganic salts, heavy metals, solids, production chemicals, detergent, hydrocarbons	A C D M P
Dehydration and Sweetening Wastes	Dehydration processes Sweetening processes	Amines, glycols, filter sludges, metal sulphides, H <sub>2</sub> S, metals, benzene	P

A = Abandonment    C = Construction and Commissioning    D = Drilling    M = Maintenance    P = Production    S = Seismic

WASTE STREAM	MAIN SOURCES	POSSIBLE ENVIRONMENTALLY SIGNIFICANT CONSTITUENTS	TYPE OF OPERATION
Domestic sewage	Living quarters	BOD, solids, detergent, coliform bacteria	A C D M P S
Drilling fluid chemicals	Chemical containers Drilling fluids Drill cuttings Rig wash	Biocides, surfactants, salts, metals, emulsifiers, viscosifiers, organics, pH	D P
Fire fighting agents	Fire protection equipment/facilities	Halons, CFCs, HCFCs, fire fighting foams	A C D M P
Hydrotest fluids	Pipeline hydrotesting activities	BOD, solids, biocides, corrosion inhibitors, oxygen scavengers, dyes	C
Incinerator ash	Incinerators	Heavy metals, salts, ash	A D P
Industrial refuse	Cleaning materials Insulation	Hydrocarbons, plastic	A C M
Industrial waste	Batteries Transformers Capacitors	Acid, alkali, heavy metals, PCBs	A C M
Maintenance wastes	Sandblast (grits) Greases Fuel oils Filters	Heavy metals, hydrocarbons, solids, solvents	M
Medical waste	Dressings Clinical & cleaning materials Blood samples	Pathogenic organisms, plastic, glass, medicines, needles	A C D M P
Mercury	Instrumentation Oil/gas production Production testing	Mercury	A D M P
Oil based muds & cuttings	Drilling operations	Hydrocarbons, inorganic salts, heavy metals, solids/cuttings, drilling fluid chemicals	D
Paint materials	Paints Thinners Coatings	Heavy metals, solvent, hydrocarbon	C M
Pigging sludges	Pipeline cleaning operations	Inorganic salts, heavy metals, solids, production chemicals, NORM, hydrocarbons, phenols, aromatics	P
Process water	Engine cooling water Brake cooling water Wash water	Hydrocarbons, treatment chemicals	A D M P S

A = Abandonment    C = Construction and Commissioning    D = Drilling    M = Maintenance    P = Production    S = Seismic

WASTE STREAM	MAIN SOURCES	POSSIBLE ENVIRONMENTALLY SIGNIFICANT CONSTITUENTS	TYPE OF OPERATION
Production chemicals	Chemicals containers Spent fluids Sludges Contaminated chemicals	Demulsifiers, corrosion inhibitors, wax inhibitors, scale inhibitors, defoamers, oxygen scavengers, biocides, coagulants, flocculants.	P
Produced water	Production of oil and gas	Inorganic salts, heavy metals, solids, production chemicals, hydrocarbons, benzene, PAHs	D P
Produced sand	Drilling/production operations	Hydrocarbons, heavy metals, NORM	P
Refrigerants	Air conditioning/ refrigerant systems	CFC, HCFC	A C M P
Scrap metals	Abandoned platforms Used pipelines Used process equipment Used tanks Electrical cables Empty drums Used tubulars Used casing	Heavy metals, NORM scales	A C M S
Spacers	Drilling operations	Hydrocarbon, alcohol, aromatics, detergents, surfactants	D P
Spent catalysts	Catalyst beds Molecular sieve	Heavy metals, hydrocarbons, inorganic salts	M P
Spent completion fluid	Production well completion activities	Inorganic salts, hydrocarbons, corrosion inhibitors	D P
Spent stimulation or fracturing fluids	Production well workover activities	Inorganic acids (HCL, HF), hydrocarbons, methanol, corrosion inhibitors, oxygen scavengers, formation fluids, NORM, gelling agents	D P
Tank & vessel bottom wastes	Separation tank sediments Storage tank sediments Water drain tank sediments	Inorganic salts, heavy metals, solids, production chemicals, NORM, hydrocarbons, PAHs	P
Waste lubricants	Equipment lube oil changes	Organics, heavy metals	D M S
Water based (include brine) muds & cuttings	Drilling activities	High pH, inorganic salts, hydrocarbons, solids/cuttings, drilling fluid chemicals, heavy metals	D

A = Abandonment    C = Construction and Commissioning    D = Drilling    M = Maintenance    P = Production    S = Seismic

## APPENDIX 5

The following pages contain descriptions of some selected waste streams and discussion of possible waste management options for these wastes. These descriptions are not intended to be all-inclusive but give examples of potential options.

### Specific Waste Information

#### ● *Atmospheric Emissions*

This covers all power plant exhausts, flares, vents and gas leaks in drilling and oil and gas processing activities.

This can include SO<sub>x</sub>, NO<sub>x</sub>, H<sub>2</sub>S, hydrocarbons, VOCs, particulates and PAHs.

#### Waste Management Options

*Reduce:* Design and operate oil and gas exploration and production activities and process equipment with controls and policies to minimise atmospheric emissions.

Maintain and run all power plants under optimal fuel efficient conditions, when possible.

*Reuse:* Where possible flare gas should be used as a fuel. Natural gas may also be injected for reservoir maintenance, enhanced recovery or used in artificial lift.

*Recycle/ Recover:* Exploit waste heat recovery opportunities where practically possible.

*Treatment/ Disposal:* Excess produced gas may be injected or flared.

Catalytic chambers, scrubbers or strippers can be installed on exhaust stacks.

Water injection into fuel combustion chambers may reduce NO<sub>x</sub> emissions.

#### ● *Chemical Waste*

This includes any surplus or contaminated chemicals used at all stages of exploration and production activities. It includes specific items such as batteries, transformers and other items containing or contaminated with chemical products.

The concerns will depend on the composition and the associated safety and adverse environmental considerations. These wastes may require specific segregation and disposal techniques.

#### Waste Management Options

*Reduce:* Wherever possible, planning and good housekeeping practices should be employed to minimise surplus and contamination.

Substitution with longer life products and those with lower impacts should be considered.

<i>Reuse:</i>	<p>Surplus chemicals may be usable in other locations or returned to vendors, if possible.</p> <p>Materials such as cement, bentonite, lime, may have alternate use in waste treatment, road construction, landfill site construction, etc.</p>
<i>Recycle/ Recover:</i>	<p>Items such as lead acid batteries, wet nickel/cadmium batteries should be sent to recycling facilities if available.</p> <p>Certain chemical wastes may contain metals such as silver or mercury which could be recovered.</p> <p>Chemical solvents may be economically recovered or used in a fuel blending programme.</p>
<i>Treatment/ Disposal:</i>	<p>Encapsulation/solidification by mixing with cement, lime or other binder may be appropriate prior to disposal.</p> <p>Special landfill sites may be available which can accept certain kinds of chemical waste. The possibility of leachate problems need to be identified.</p> <p>For some organic chemical wastes, incineration may be the preferred treatment option. For chemicals like PCBs, high temperature incineration is required to destroy the compounds.</p>

● Contaminated Soil from Oil/Fuel Spills

This may include soil, beach or shore materials arising from the leakage or spill of hydrocarbons or fuels.

The impact will depend on the type of hydrocarbon and the location of the spill or leak.

**Waste Management Options**

<i>Reduce:</i>	Avoid spills and leakage by improved housekeeping, maintenance and transport procedures.
<i>Reuse:</i>	N/A
<i>Recycle/ Recover:</i>	Depending on the extent of the contamination, recovery of free liquids may be possible.
<i>Treatment/ Disposal:</i>	<p>Landfarming, landspreading and composting may be applicable if conditions for biological degradation are favourable. Enhancement techniques could be considered.</p> <p>Incineration, landfill and burial options may be limited by availability and the quantity/nature of the contaminated soil.</p> <p>Stabilisation techniques may be applicable prior to disposal.</p>

### ● *Drilling Pit Waste*

Drilling pit wastes usually contain both solid and liquid components. Constituents of environmental concern include salt, hydrocarbons, pH, drilling chemicals and biologically available heavy metals. These constituents have the possibility of impacting soil and water quality.

#### **Waste Management Options**

*Reduce:* The volume of drilling pit wastes may be reduced by judicious use of rig wash water, by releasing water that does not contain hydrocarbons or high salinity from the pit, by avoiding the collection of rainwater run-off in the pit or by reusing the water in the drilling fluid.

Drilling waste volume may be minimised by the use of a closed loop mud system.

*Reuse:* Solids may be applicable for the lining or capping of landfill sites, or as a road construction material.

*Recycle/ Recover:* Recovered weighting materials and drilling fluids may be recycled into the drilling fluid of the same or different well.

Commercial mud plants may take used drilling fluids for recycle.

*Treatment/ Disposal:* Options for the disposal of aqueous drilling pit wastes include surface discharge and injection. Before the aqueous phase can be surface discharged, it should be treated to remove hydrocarbons and excess suspended solids and to adjust the pH to within the acceptable range. The dissolved salt and biologically available metal content must be at a level which will not cause an adverse impact on the receiving environment. Liquids which cannot be treated to a standard suitable for surface discharge may have to be injected.

The options for management of solid drilling pit wastes include burial in the pit; landfarming, landspreading or composting to reduce organic content; thermal treatments to recover or destroy organics; injection; and stabilisation or solidification.

### ● *Drums/Containers*

Metal and plastic containers are used for a wide range of lubricants and chemicals used throughout the industry. The accumulation and disposal of these can be problematic. Drums and containers inevitably contain variable quantities of residues. The impact arises from both the volume and presence of residues.

#### **Waste Management options**

*Reduce:* Bulk transport and storage should be considered for high volume consumption items.

*Reuse:* Certain containers can be refilled from bulk storage and reused. Where possible, non-refillable containers should be returned to the vendor for reuse, or to a company specialising in container refurbishment.

Drums and containers can be used for the transportation of suitable wastes provided safety considerations are not compromised.

*Recycle/ Recover:* Both metal and certain plastic drums and containers may be recycled if outlets are available. However, this may require that they be cleaned of any residues beforehand.

*Treatment/ Disposal:* Drums should be crushed prior to landfill. The nature of any residues may restrict this option or require pre-cleaning.

Incineration may be applicable to plastic containers, but incinerators may need to be equipped with air pollution control devices.

#### ● *Garbage–Inert Solid Waste*

This includes wood, plastics, paper, food waste, general garbage and inert construction and maintenance materials.

The environmental impact may arise from the encouragement of vermin by food wastes, production of gases by biodegradable materials and leachates where other site materials such as chemical residues have been mixed in with the waste.

#### Waste Management Options

*Reduce:* Packaging wastes such as paper and plastic can be reduced by the use of bulk handling systems or 'big bags'.

Segregation of components such as wood, plastic and paper, for recycling or reuse will reduce the quantity for disposal.

*Reuse:* Where the inert waste consists totally of construction material, it may be usable as infill.

*Recycle/ Recover:* Materials such as wood, paper and metals may be segregated for recycling.

General garbage is frequently incinerated and some incinerators are fitted with heat recovery.

*Treatment/ Disposal:* Landfill is the most common disposal method employed. Local conditions may limit this option. Burial of these wastes may be an option when a suitable landfill is not available.

Incineration using fixed or mobile facilities will greatly reduce the waste volume for landfill.

Techniques such as composting may be used to reduce the volume of domestic waste through biodegradation.

#### ● *Pit, Tank and Vessel Bottom Wastes*

This waste consists of water, accumulated hydrocarbons, solids, sand and emulsions which collect in the lower sections of slop oil tanks, crude oil stock tanks, closed water drain tanks, open water drain tanks and other

storage and separation vessels as well as in produced water storage or emergency pits.

Constituents of these wastes that may impact selection of waste management and disposal methods include hydrocarbons, salts, metals, production chemicals and occasionally NORM. Possible environmental impacts will depend on the concentrations of these constituents and the waste management option(s) chosen.

#### Waste Management Options

*Reduce:* Improved housekeeping procedures may reduce the volume of solids collected in drainage water storage tanks. The waste volume may be reduced through evaporation or dewatering.

*Reuse:* Suitable wastes may be mixed with absorbent material (e.g. lime) and applied as road surfacing material, or mixed with aggregate in an asphalt batch process.

*Recycle/ Recover:* Sludges containing significant oil may be reclaimed either onsite or offsite for the removal and recovery of hydrocarbons.

*Treatment/ Disposal:* These sludges may be landfilled, if dry.

These sludges may be landspread or landfarmed. Consideration will have to be made of the biodegradability of the organics, availability of land, loading rates, and possibility of ground or surface water contamination.

These sludges may be incinerated, with proper pollution control devices in place.

#### ● Process Drainage Waste System

The process facility drainage system wastes will include washdown water, boiler and cooling water blow downs, leaks and spills. The hazards will depend on the nature of the sources. As with surface water drainage, physical effects such as erosion and temperature may be considerations.

#### Waste Management Options

*Reduce:* A leak minimisation strategy should form an integral part of facility design and maintenance procedures. All fuel, hydrocarbon and hazardous chemical storage areas should be sufficiently banded. Drip pans should be used where needed.

Spill clean-up procedures should be developed.

*Reuse:* Process water may be reused for activities requiring lower water quality (e.g. rig washing or flare suppression).

*Recycle/ Recover:* N/A

*Treatment/ Disposal:* See rainwater drainage

### ● *Produced Water*

Originating from oil and gas production/processing, produced water will contain variable quantities of mineral salts, solids, suspended and dissolved hydrocarbons, and other organic and inorganic components, and may be at high temperature. The composition may change with time. It may require pre-treatment prior to disposal.

The environmental impact will be highly dependent on the quantities involved, the components, the receiving environment and dispersion characteristics.

Before significant or long-term discharge of produced water to the environment is carried out, an environmental impact study should be carried out.

#### **Waste Management Options**

*Reduce:* Water shut off treatments, re-perforation.

*Reuse:* Re-injection for reservoir pressure maintenance or secondary recovery of oil.

Quality may allow use for agricultural purposes or reuse as wash water.

*Recycle/* Heat content.

*Recover:* De-salination.

*Treatment/* Surface discharge into the environment may be possible  
*Disposal:* depending on the water quality, volume and flow. Primary treatment such as de-oiling will often be required. Bio-treatment may be practical for low volumes.

Downhole injection to suitable formations other than the producing formation may be possible. However, the possibility of contaminating usable water aquifers must be taken into account.

Evaporation and subsequent disposal of salts may be possible.

### ● *Rainwater Drainage*

This will come from all areas of the site/facilities. Surface drainage will be susceptible to contamination from spills, leakage and leaching. The environmental impact will depend on such contamination along with physical considerations such as erosion.

#### **Waste Management Options**

*Reduce:* Contamination of the surface drainage water should be avoided as this will be considerably easier than any subsequent treatment. Thought should be given to the segregation of drainage from liquid storage, loading/unloading facilities, and operations areas from unimpacted areas of the site.

*Reuse:* Collected rainwater could be reused for agricultural purposes if quality permits or could be used for activities requiring lower water quality such as washing or flare suppression.

*Recycle/* N/A

*Recover:*

*Treatment/Disposal:* Surface disposal may be governed by contamination. The provision of a site drainage system with an oil/solids interceptor should be considered. Any surface disposal option should be capable of taking the drainage volumes without causing damage by erosion or flooding, which would not otherwise occur.

Drainage water with a high organic content may be treated in biological water treatment systems to remove organics prior to discharge.

### ● *Sanitary Waste*

This covers all sewage and foul drainage. The impact will be associated with the BOD, Coliform bacteria and treatment chemicals.

#### **Waste Management Options**

*Reduce:* Low flow and low water use toilets may be used.

*Reuse:* N/A

*Recycle/Recover:* Digested sewage sludge may be used for agricultural/land improvement purposes.

*Treatment/Disposal:* Full treatment septic systems to process all sewage should be installed for all construction, drilling and production facilities, and camps on land. Consideration may be required for marine sewage systems for large offshore rig or platform operations.

If chlorination is carried out, this should be strictly controlled and oxygenation may be required to prevent damage to aquatic life.

## APPENDIX 6

### Waste Management Options— Summary Table

This table summarises the waste minimisation options and possible treatment and disposal methods that may be applicable to a variety of wastes typically found in E&P operations.

This list is not exhaustive, and the minimisation, treatment and disposal methods may vary according to available facilities, local conditions and regulatory requirements. Indication in the table that minimisation options may exist does not necessarily mean that a significant reduction in waste volume can be reasonably achieved. Similarly, indication that a treatment or disposal option may be applicable does not necessarily mean that it will be appropriate or effective for specific waste streams or all environments. Combinations of treatment and disposal methods may be required to meet management objectives.

#### Treatment and Disposal Methods

A = Deep Well, B = Evaporation Ponds, C = Specialised Waste Disposal Facility, D = Incineration, E = Land Treatment, F = Landfill, G = Biological Treatment, H = Road Application, I = Solidification, J = Bioremediation, K = Surface Water Discharge (may require pretreatment)

Waste Name	Minimisation Options			Treatment and Disposal Method										
	Reduce	Reuse	Recycle	A	B	C	D	E	F	G	H	I	J	K
Acid	•	•	•	•	•	•								•
Activated Carbon	•		•			•	•	•	•					
Batteries, Lead Acid, Wet NICAD			•			•			•					
Catalysts	•	•	•	•					•					
Caustic	•	•	•	•					•					•
Chemical Waste	•	•	•			•	•		•			•		
Construction & Demolition Material	•	•	•				•		•					
Containers—Drums/Barrels	•	•	•			•	•		•					
Contaminated Debris & Soil—Chemicals	•		•			•	•		•			•		
Contaminated Soil—Hydrocarbon/Fuel	•		•			•	•	•	•			•	•	
Dessicant	•	•	•				•		•					•
Drilling Pit Waste	•	•	•	•		•	•	•	•		•	•	•	•
Filter Backwash Liquids	•		•	•	•									•
Filters, Chemical Treatment	•					•	•		•					

Waste Name	Minimisation Options			Treatment and Disposal Method										
	Reduce	Reuse	Recycle	A	B	C	D	E	F	G	H	I	J	K
Filters—Lube Oil	•					•	•		•					
Filters—Other (Raw gas, fuel, air)	•					•	•		•					
Filters—Water	•						•		•					
Garbage—Domestic Waste	•		•				•		•				•	
Hydrotest Fluids		•		•		•								
Incinerator Ash			•	•		•			•			•		
Insulation		•				•			•					
Ion Exchange Resins	•	•	•						•					
Ion Exchange Resin—Regenerant Liquids	•	•	•	•										
Iron Sponge								•	•					
Laboratory Chemicals	•		•	•		•	•		•					
Lubricating Oil—Hydrocarbon	•		•				•							
Lubricating Oil—Synthetic			•			•								
Molecular Sieve			•						•					
Paint Associated Wastes	•	•	•			•	•		•					
PCB—Contaminated Solids & Liquids						•								
Pigging Waste Liquids/Wax			•			•	•							
Process Waters	•	•		•										
Produced Sand	•					•		•	•		•		•	•
Produced Water	•	•	•	•	•					•				•
Rags—Oily	•	•	•				•		•					•
Rainwater Drainage	•	•								•				•
Scrap Metal	•	•	•						•					
Sludge, Glycol systems			•			•	•	•	•					
Sludge, Gas Sweetening	•		•			•	•		•			•		
Sludge, Tank & Vessel Bottoms	•	•	•			•	•	•	•		•		•	
Sludge, Water Treatment							•		•			•		
Sanitary Wastes	•		•							•				•
Well Workover Fluids	•	•		•		•	•							•