Managing Waste in Exploration and Production Activities of the Petroleum Industry

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Abstract

Sustainable development of petroleum resources requires appropriate management of all waste streams generated over the entire life cycle of this development beginning with initial planning of projects and operations right through to decommissioning and site restoration. Hence a quality waste management approach became crucial to achieve this goal. The principle aim of waste management is to ensure that waste does not contaminate the environment at such a rate or in such a form or quantity as to overload natural assimilative processes and cause pollution. Eliminating or minimising waste generation is crucial, not only to reduce environmental liabilities but also operational cost. Many disposal practices of the past are being questioned now. The cost of cleaning up many past hazardous waste sites will be high and a substantial part of these clean-up costs will be charged to industry under the polluter pay principle. As inadequate waste handling eventually leads to environmental damage and financial liabilities, systematic waste management through integrated environmental economics became a preferred approach in the up stream phase of the petroleum industry.

This paper discusses basic concepts for managing waste generated during upstream operations and provides systematic approach for pro-active waste management practices. It provides a framework that can be used to develop classification systems in line with local requirements, while maintaining consistency with industry standards. It addresses the various stages in waste management, and emphasizes the phases of identification, characterization, inventorisation, segregation, minimization, treatment and disposal as integral parts of the waste management process. It emphasises the importance of proper classification of waste streams, focusing on pragmatic assessment of environmental hazards at all stages in the waste life cycle. Some practical aspects of classifying waste in the context of exploration and production operations in the petroleum industry are also given

Introduction

Effective and responsible waste handling and disposal are key elements of any environmental management system. 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.

With the increased acceptance and adoption of sustainable development approach to manage project development in the petroleum industry, quality waste management techniques became essential. The principle aim of waste management is to ensure that waste does not contaminate the environment at such a rate or in such a form or quantity as to overload natural assimilative processes and cause pollution. Eliminating or minimizing waste generation is crucial, both environmentally and economically, for reducing waste-related liabilities and cost. Many disposal practices of the past are being questioned now. The cost of cleaning up many past hazardous waste sites will be high and a substantial part of these clean-up costs will be charged to industry under the principle that the polluter should pay. As inadequate waste handling usually leads to environmental damage and financial liabilities, systematic waste management through integrated environmental economics is thus, the preferred approach.

This paper describes the basic concepts for managing waste generated during upstream operations and provides systematic approach for pro-active waste management practices during the various stages of petroleum exploration and production.

Definitions

Although many definitions of waste are used by the industry and international organizations the definition used in this paper is the most commonly used in the petroleum exploration and production, E&P, industry:

E&P Waste is defined as any unavoidable material resulting from an up-stream operation for which there is no economic demand and which must be disposed of.

In the absence of well-defined legislative classification for waste produced in up-stream operations, there are usually three types of waste distinguished:

- Domestic waste (office and households);
- Special waste (hazardous to health and/or the environment);
- Industrial waste (generated during petroleum activities and which is neither domestic nor special).

For the purpose of this document:

Special waste is defined as any liquid or solid waste, which because of its quantity, physical, chemical or infectious characteristics can result in hazards to human health or the environment when improperly treated, stored, transported or disposed.

Objectives

Objectives of quality waste management are to:
- avoid production of waste;
- ensure environmentally sound waste management practices;
- meet projected targets and horizons;
- avoid financial and legal liabilities;
- reduce cost through integration of economically viable environmental measures; and

Scope

Waste management is virtually applicable to almost all upstream operations starting from seismic to drilling, field development, production and ending with abandonment phases. The waste management process goes through several consecutive steps; identification, characterization, inventorisation, minimization and disposal of waste including recording and reporting its dispositions. Developing the optimum waste management plan should progress through the steps shown in Fig. (1), although, in some cases there may not be a sharp boundary with respect to sequence:

1. Environmental Management System's requirements;
2. Identification;
3. Characterization;
4. Inventorisation;
5. Minimization;
6. Disposal;
7. Handling and reporting;
8. Plan integration.

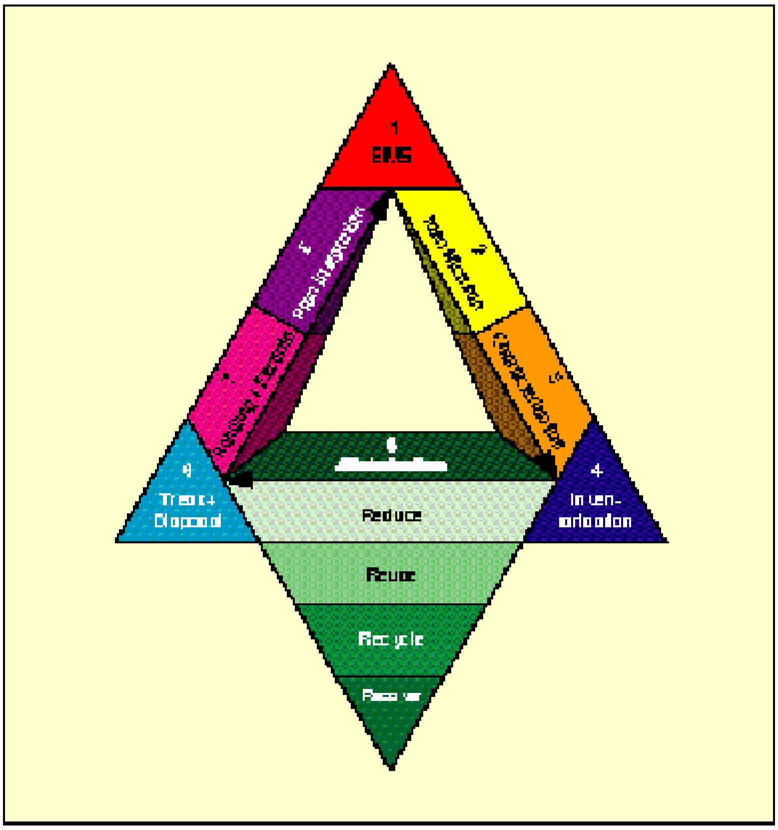


Fig. 1. Waste Management Process

1. Environmental Management System. EMS

As a starting point it is essential to consult the EMS document to ensure awareness of policy and management requirements particularly:

- policy statement;
- environmental objectives and targets;
- legislative requirements and trends;
- line management responsibilities;

- socio-economic aspects;
- auditing and reporting requirements.

2. Identification

All relevant waste management issues should be identified to determine potential problems and select the optimum strategy for subsequent steps. A logical sequence would be to identify:

2.1 Area of coverage

In other words the area in which waste will be managed. Such areas can be defined on the basis of the following aspects:

- *Geology*; certain geological and hydrogeological aspects of the area may influence waste management options. Marine environment conditions differ from onshore or remote desert conditions.
- *Site specific*; climatology, topography, suitability for landfills and landfarming will influence disposal options.
- *Operations*; type of operation will obviously influence the waste generated. Seismic crews will have different types of waste than a drilling rig or gas processing plants.

2.2 Wastes in an area's operations

Once an area is defined, all waste streams generated by operations need to be identified. This is best done on a process by process basis. Typical discharges from primary processes in upstream operations as well as their main components and environmentally significant constituents are listed in Annex I, (Ref. 2).

3. Characterisation

The purpose of waste characterisation is to determine whether or not the waste is hazardous. The physical and chemical properties of the waste influence its hazardous characteristics and environmental impact ability. Waste characterization is also required to determine and assign the waste stream categories and select options for segregation, minimization, treatment and ultimately disposal.

Generally, a waste may be classified as hazardous and consequently falls under the "special waste" category when it meets one of two conditions:

- the waste is specifically regulated by a governmental authority or an internationally recognized organization, or
- the waste possesses one or more of the four hazardous characteristics: ignitability, corrosivity, reactivity or toxicity. Table 2 gives guidance for hazardous characteristics in general.

3.1 Regulated waste materials

These will include any waste material which is specifically regulated as hazardous by a governmental authority based on its ability to cause cancer, birth defects, and/or its toxicity to humans and other ecosystems. In the absence of governmental regulations, guidelines issued by relevant international or regional organisations should be used.

3.2 Ignitability

This will apply to liquids, solids or gases; however, the most common are liquids or solutions which have a flash point of 23°C or below. Other materials included in this class are oxidisers which readily yield oxygen to support the combustion of organic materials, waste which can spontaneously combust, and flammable compressed gases. Examples of ignitable wastes include acetone, hexane, methanol, and isopropanol.

3.3 Corrosivity

This classification applies to liquids only. A waste is corrosive if its pH is equal to or less than 2, or equal to or greater than 10. Liquids which corrode steel at rates greater than 6.35 mm/yr are also considered corrosive. Examples of corrosive waste include mineral acids, sodium, and potassium hydroxide.

3.4 Reactivity

This classification encompasses two types of hazards-physical and health. Wastes with reactive physical characteristics are those with the potential of reacting violently, presenting fire hazards, and/or capable of explosion at normal temperatures and pressures. Wastes with reactive health hazards are those which will release toxic or irritating vapours or fumes when mixed with water or acids. Examples are reactive laboratory wastes, such as cyanide or sulphide solutions, and water-reactive metals.

3.5 Toxicity

This classification includes those substances which are capable of causing acute, chronic or adverse effects in humans and/or the environment. Examples of toxic wastes include biocides, carcinogens and heavy metals such as lead, chromium and arsenic.
Generally, a waste is considered non-hazardous if it does not possess any of the above-mentioned characteristics, however extreme caution must be used when following these guidelines. Although some materials do not fall into these hazard classes, they still may pose a threat to the environment or humans and should be handled accordingly. The following are known as most important polluting substances (Ref. 3).

- Sulphur dioxide and other sulphur compounds
- Oxides of nitrogen and other nitrogen compounds
- Carbon monoxide
- Organic compounds, in particular hydrocarbons (except methane)
- Heavy metals and their compounds
- Dust, asbestos, glass and mineral fibres
- Chlorine and its compounds
- Fluoride and its compounds.

3.6 Environmental sensitivity

Assessment of the sensitivity of a receiving environment to specific contaminants is essential for categorising the waste stream. Such assessment can be done in accordance with recommended procedures, (Ref. 2) using the Black and Gray lists techniques. Table 2 shows a sensitivity matrix for some specific contaminants and Table 3 includes the Black list and Grey list components.

3.7 Categorisation and ranking

In order to rank the waste streams in terms of environmental impact, proper assessment of the critical elements, discharged quantities, ultimate fate of the contaminants and the assimilative capacity of the environment has to be carefully considered. Due to the complex nature of these factors, only a qualitative approach can be adopted at the present time (Ref.4). The most important wastes produced in E&P activities are aqueous discharges, atmospheric emissions and solid waste. Detailed assessment of the most environmentally significant components and their likely quantities in those waste categories has provided the following potential ranking structure:

Ranking of E&P aqueous discharges

Environmental ranking	Source	Environmentally significant components
1	Produced water	Hydrocarbons, inorganic salts, heavy metals, solids, organics, sulphides, corrosion inhibitors, biocides, phenols, BOD*, organo-halogens, PAH**, radioactive material
2	Process water, e.g. filter-backwash water, cooling water	Inorganic salts, heavy metals, solids, organics, BOD, sulphides, corrosion inhibitors, biocides, demulsifiers, wax inhibitors, detergents, hydrocarbons
3	Hydro-test water	BOD, corrosion, products, biocides, corrosion inhibitors, oxygen scavengers, dyes
4	Ballast water	Hydrocarbons, phenols, PAH
5	Contaminated rain/ drainage water	Inorganic salts, heavy metals solids, organics, BOD, sulphides, corrosion inhibitors, biocides, emulsifiers, wax inhibitors, scale inhibitors, detergents, hydrocarbons
6	Domestic sewage	BOD solids, detergents, coliform bacteria

* Biological Oxygen Demand

** Poly Aromatic Hydrocarbons

Note that wastes can enter the aquatic environment from a number of sources:

- discharge or seepage of liquid effluents,
- leakage of process or pipeline systems,
- via atmospheric fall-out.

Ranking of E&P atmospheric emissions

Environmental ranking	Source	Environmentally significant components
0*	Firefighting agents	Halons
0*	Refrigerants	CFC's
1	Vent gases	CH_4, H_2S
2	Flare gases	CO_2, NO_X, SO_2, particulates
3	Exhaust gases	CO_X, NO_X, SO_X, particulates, hydrocarbons
4	Fugitive gases	Volatile organic compounds (VOC)

* Phased reduction of Halons and CFS's has already been agreed internationally under the Montreal Protocol of 1987 as amended in Copenhagen in 1992.

Atmospheric emissions generated by E&P activities arise from three main sources:

- burning of fuel;
- venting and flaring;
- fugitive emissions.

Ranking of E&P solid waste

Environmental ranking	Source	Environmentally significant components
1	Tank/piping sludges, IGF/DGF* sludge, waxes	Inorganic salts, heavy metals solids, organics, BOD , sulphides, corrosion inhibitors, biocides, demulsifiers, wax inhibitors, scale inhibitors, phenols, PAH, hydrocarbons
2	Production chemicals	Demulsifiers, corrosions inhibitors, wax inhibitors, scale inhibitors, antifoaming agents, biocides, oxygen scavengers
3	Industrial refuse	Heavy metals, metals, plastics, paints
4	Soil movements owing to e.g. abandonment and construction	Hydrocarbons, heavy metals, metals, plastic, paints, glass
5	Domestic refuse	Plastics, glass, organic waste

*   IGF = Induced Gas Floatation unit   DGF = Dissolved Gas Floatation unit

The principle concerns for disposal of waste materials to the land are:

- toxic contaminants in the soil may enter the food chain and may contaminate water,
- damage may occur to terrestrial ecosystems.

In conclusion waste characterisation, categorisation and ranking at present are rather a difficult but an important task where the waste streams tend to reflect the variation of input quality while planned products must confirm to exact specifications. It is anticipated that future regulatory control will specify the composition and characteristics of all waste streams. It will therefore be necessary to identify, monitor and control their composition throughout the various activities. Equally important is the segregation of waste streams in order to facilitate inventorisation and subsequent management.

4. Inventorisation

4.1 Criteria

Inventorisation means monitoring and recording of quantities and qualities of effluents and wastes. The objective of inventorisation is to account for all identified emissions effluents and wastes, in particular their quantities, in order to provide the data required for their management. It helps to identify operations in which waste generation can be reduced, preferably at source, through an improvement in operational practice or by improvements in design. This may result in higher efficiency, better use of resources and therefore in cost savings. E&P activities generate considerable volumes of effluents and wastes that are disposed of to air, water or land, including reinjected effluents. These should be all inventorised. The inventory should also contain the quantities that are being discharged and the location of the discharges.

4.2 Waste inventory data base

Data on emissions and discharges can be obtained from:

- direct measurements of contaminant mass flows;
- application of generic factors for each contaminants and source, e.g. fugitive emission factors derived from industry standards.

Techniques for estimating the quantity and composition of discharges and emissions from operations vary with respect to "order of magnitude The method to be adopted will depend greatly upon the source of the waste streams and existing knowledge of the likely contaminants and their concentrations. While direct measurement schemes exist for most emissions, it is normally adequate to apply suitable emissions factors. For instance, although fugitive emissions can be measured, recognized leakage factors have been established for each component part of a facility.

By knowing process flow conditions, feed composition and combustion properties, it is possible to derive concentrations of combustion products such as nitrogen oxides, and carbon monoxide. Mass balances of chemicals used or contaminants generated can be calculated to provide quantitative information on the distribution of compounds in process, effluent and waste streams, and therefore complete the list of environmentally significant constituents.

These mass balance data can be compared with the results of chemical analysis of spot samples of discharges before deciding whether additional chemical analyses are required. In general, a detailed desk mass balance calculation should be carried out when established hazardous chemicals are used. In addition, a desk mass balance should be calculated when there is uncertainty about the actual concentrations of chemicals in the discharge, e.g. demulsifier in production water effluent

4.3 Updating the inventory

Compilation of the inventory will be a laborious process on the first occasion. However, subsequent updating should be relatively easy. It must be realised that the inventory should be updated whenever there is a change in either type, composition or location of discharge. For example a change in the chemicals used in the production process will mean a change in the inventory for the production water effluent.

4.4 Atmospheric emissions mass & energy balances

- **Emission calculations**

Emissions of carbon dioxide, carbon monoxide, nitrogen oxides, sulphur dioxide, hydrogen sulphide and hydrocarbons should be calculated for each combustion and non-combustion process at each location. The combustion processes include flare, flare purge, furnaces, gas turbines, diesel turbines and diesel engines. Non-combustion sources should include vented gases, emergency gas release and fugitive emissions.

- **Mass and energy balances**

Where the endpoint of fossil fuel exploitation is ultimately the release of carbon dioxide, the principal tool for tackling CO_2 emissions is to increase energy efficiency. Mass and energy balances should be calculated for all installations, based on monthly operating data. These balances serve a number of functions. Waste energy is identified , as well as providing basic information on waste streams, and quality control on the emission data produced.

4.5 Aqueous discharges

There can be several sources of planned aqueous discharges from upstream activities:

- **Produced water**

The properties of produced water vary from field to field. Generally, it is saturated with dissolved gases including CO2 and possibly H2S as well as hydrocarbons. These gases come out of solution as process pressures are reduced. In addition to gases, the produced water contains large amounts of dissolved salts and chemicals both from the original formation water and those used in injection water in production systems. These are present either in their original form or as new compounds created by temperature, pressure or their association with other chemicals. Dispersed and dissolved hydrocarbon levels in produced water have to be monitored.

- **Drilling discharges**

Drilling muds consist of a slurry of solid materials suspended in a liquid phase. They may be water-based muds or oil-based muds. The original types of oil based muds used diesel for the oil phase, but present systems use refined oil which has had most of the toxic aromatic fraction removed. Both water and oil based muds are stabilised using a range of drilling chemicals to enhance their performance.

During operations, rock cuttings are discharged. Some mud remains adhered to these cuttings while other mud is incidentally lost. At the end of drilling operations, remaining water-based muds may be discharged, while oil-based mud is usually recycled.

- **Cooling water**

Water is used to cool power and process plants; depending on availability of supply of water, either a once through system or a recirculating system is installed. The cooling water should be continuously or routinely dosed with a variety of chemicals to prevent macro and micro fouling and to reduce the corrosion rate.

- **Sewage**

Domestic sewage from washrooms, canteens, laundry and accommodation modules falls into two distinct categories. Black water describes excreted waste and Grey water describes all other water discharges associated with kitchens and personnel hygiene. Sewage, in addition to containing a substantial quantity of organic matter, has associated with it heavy metals. In addition nutrients, particularly nitrogen and phosphorous compounds, are present in all domestic waste water streams.

- **Drainage water**

Drainage water is a collective term used to describe process drainage, rain water, sea spray and incidental operational discharges. The water may on occasions such as oil spills or overflow be contaminated with suspended solids such as when drilling muds contaminated the drainage water. The water will also contain contaminants such as operational chemicals including cleaning detergents and surfactants.

4.6 Disposed to land

All waste material, deposited onshore, should be monitored and inventorised according to the following categories:

- **Special waste**

Is, or may be "so difficult or dangerous to dispose of, or special provision is required for its disposal". Examples inlude paints, solvents, asbestos and chlorinated hydrocarbons.

- **Industrial waste**

Is waste resulting from processes and operations and construction waste, dredging spoils and sewage disposal on land. It includes metal scrap, waste oil, waste mud and tank washings.

- **Domestic waste**

Is waste from kitchens and domestic refuse, paper, litter, waste from premises used wholly or mainly for the purposes of offices, living accommodations and administration facilities.

5. Minimisation

Waste minimisation means the reduction to the greatest extent practicable, of the volume, or relative toxicity of wastes that are generated and require disposal. Wastes besides their potential liabilities should be seen as inefficiencies that create undue costs. A pre-requisite step for minimisation is waste segregation into separate streams which should be suitable for minimisation options.

A sound approach to bring about effective minimisation is by applying the rule of the "4 R's" Reduce, Reuse, Recycle and Recover.

R*educe* means reduction at source. It can be achieved by either generating less waste through more efficient practices or by replacing hazardous materials with benign or less harmful materials thus improving the quality of waste. However, the best practice is to reduce at source preferably at the design phase.

R*euse* means re-using materials in their original forms. Examples range from production water into enhancing recovery projects to chemical containers.

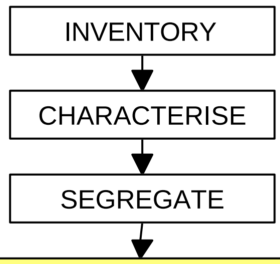
R*ecycle* means converting waste back into a usable material. Examples range from reconditioned tubular goods to motor oils, solvents and batteries. The recent successful recycling of water base muds to be used as slag mix mud into cement conversion technology did not only prove to be environmentally superior to portland cements, but also an extremely cost-affective process. The process can bring about as much as 10% reduction in mud waste streams.

R*ecover* means extracting materials or energy from a waste for other uses. Examples, include vapour recovery systems, extraction waste heat-recovery and plasma methods. The successful use of oil base mud cuttings as a feedstock material in the brick manufacturing industry is a promising application.

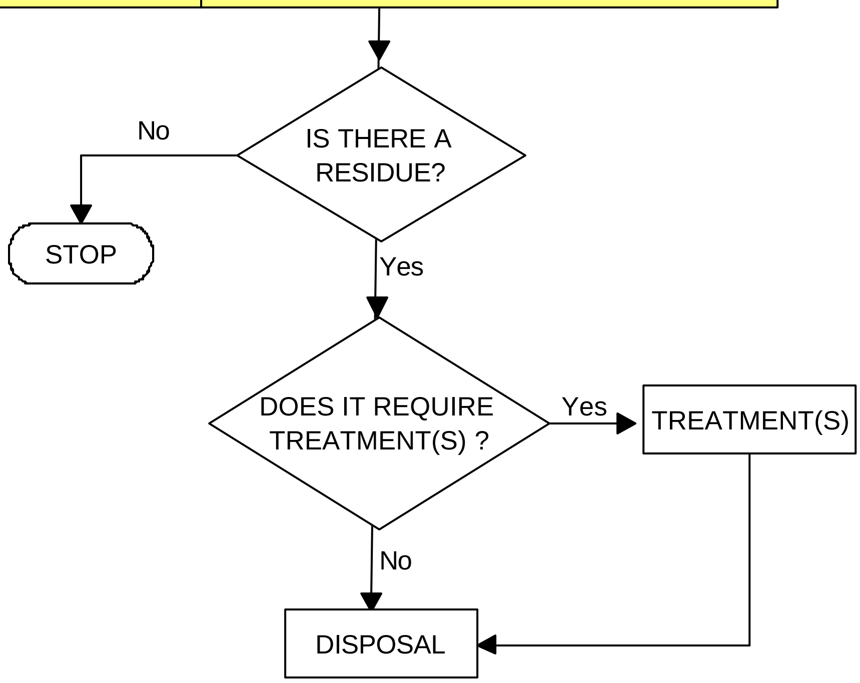
It is also obvious that all these "4 R's" options could bring about substantial economic benefits provided they are properly implemented.
Cost reduction can be achieved by savings in raw material and production costs, savings in time and energy, lower waste treatment and disposal costs and avoidance of liabilities, reinstatement and clean-up expenses.

The flow diagram shown in Figure 2 below displays how these waste management practices may be applied.

Figure 2 Key waste handling minimisation and disposal decisions



Minimisation	Examples
REDUCE	• Process modification or design change • Material elimination • Inventory control and management • Material substitution • Improved housekeeping
REUSE	• Chemical containers • Oily wastes for road spreading • Cleaned drill cuttings for roadbed material or landfill cover
RECYCLE/ RECOVER	• Recycle scrap material • Recycle paper • Recycle drilling muds • Burn waste lubricating oil for energy recovery • Recover oil from tank bottoms, produced water and drilling muds



Setting specific targets for waste minimisation in annual plans will enhance proper implementation. Annex 2, includes a check list for points to be considered when planning minimisation.

6. Treatment and Disposal

Even after adequate minimisation there will always be some wastes requiring treatment and ultimately disposal.
Treatment and disposal options depend largely on the waste characteristics and regulatory requirements. Available methods are usually limited by ecological, technical or economic factors. Waste treatment aims at reducing waste's toxicity or hazardous properties through chemical, physical, thermal or biological processes.
Table (5) shows currently used processes. Disposal of water and waste-treatment by-products includes many options. The most commonly known are; secure landfills, landfarming, incineration, deep-well injection and annular injection of drilling fluids and cuttings

6.1 Secure landfills

Secure landfills are specially designed land structures which employ protective measures against off-site migration of contained chemical waste via leaching or vaporisation. "Environmentally sound" secure landfills are constructed with double-layer clay or synthetic liners and a system of pipes designed for the collection and control of rainwater and leachates from the landfills.

6.2 Land farming

Landfarming involves spreading the waste on a designated area of land and working it into the soil. It may be safely utilised as a means of immobilising and biodegrading many oilfield wastes. Soil loading capacity must be known and should not be exceeded in order to maintain aerobic condition and control odours at site.

6.3 Incineration

Controlled incineration is one of the best treatment disposal options because thermally treated wastes are decomposed to non- or less hazardous by-products. Controlled incinerators operate at sufficient temperatures for complete thermal decomposition of hazardous wastes. In addition, solid and gas emissions are controlled by afterburners, scrubbers, and/or electrostatic precipitators.
Non-hazardous and hazardous solids, liquids, and gases can be incinerated. However, incineration of heavy metals such as lead, mercury or cadmium is
not recommended because these metals remain in the fly ash and present a leaching hazard when placed in a landfill.
Other waste-treatment by-products such as lab packs, solidified wastes, and solids from sedimentation treatments may be further treated by incineration. Additionally, some waste minimisation disposal techniques result in a waste by-product that may be burned directly or used as an incinerator fuel supplement.
As noted, the advantages of incineration are numerous, including volume reduction, complete destruction rather than isolation, and possible resource recovery.

6.4 Deep-well disposal

This includes disposal of raw or treated waste by injecting waste into deep wells where it is contained in the pores of permeable subsurface rocks far below freshwater aquifers. The primary disadvantage of this option is the possibility of freshwater contamination due to casing failure. Availability of the disposal option is also limited to certain geological settings.

Wastes suitable for disposal by deep-well injection include brines, neutralised acids and caustics, and broken-gel solutions.

6.5 Annular injection of muds and cuttings

This involves the process of slurrifying and injecting down the well annulus,all cuttings and liquids generated as waste at the drill site. This increasingly accepted method has several advantages. Beside the obvious waste reduction achievement, provision of the option for drilling with oil-based muds in environmentally sensitive areas is also clear.

7. Handling and reporting

Having decided on the treatment and disposal options, the handling of waste streams and reporting requirements should be carefully selected. Handling involves transportation on and off-site, packaging, storage, fencing and securing waste sites. It also may involve use of contractors. Reporting of waste streams movements, dispositions and handling as well as recording their specifics is a very important feature for adequate waste management.
The following points should be considered for handling and reporting of waste streams:

- On-site waste storage should be kept to a minimum.
- Transportation means should be carefully selected and checked with respect to HSE requirements.
- Transporters of waste should be provided with instructions on how to handle emergency situations.
- Use of a waste "manifest" to enable tracking of each batch of waste from its generating source to its final disposition.
- Adequate records on waste details such as dates, quantities, waste in storage, being transported, treated and disposed of, should be kept and in case of landfills and/or sea disposal, it is essential that site records are held for an indefinite period.
- When using contractors the following should be verified:
  - Contracts with waste contractors contain appropriate provisions on health and environmental protection,
  - Waste materials transferred to contractors are packaged and labelled appropriately, and shipping notification and documentation completed in accordance with approved procedures,
  - Waste consignments reach the specified final disposal site and are disposed of in an environmentally sound manner.

8. Integrated waste management plans

The selected waste management techniques and options ultimately should be compiled into an action plan for each specific operation area. Successful implementation of those selected options requires that they should be communicated effectively to the operations personnel generating and handling the wastes. Attention must be given not only to the content of those selected options, but also to the format in which those options are presented.
With operations personnel providing input for the option-selection exercise, the plan document should be substantively practical and useful to operations. Yet, for the document to be accepted and truly functional, it must be written in a style and format that is appropriate for the primary user group - field operations personnel. More specifically, the primary users of the document are the first- and second-line production and drilling supervisors. These supervisors are often the focal point for implementing new policies and requirements generated by management and engineering personnel. It is important that they are provided with clear, concise directives on what is required of their operations. These directives should

include appropriate background and details. Other users of the plan document are engineers, management, environmental professionals, and field personnel.
To provide a concise, straightforward procedure and an appropriate amount of detail, those selected options in the plan should be clearly incorporated in all the relevant environmental procedures. In documenting the waste management plan the following should be considered:

- The plan should be compiled and maintained by an environmental engineer familiar with field operations,
- Operations personnel should provide input for plan's development and maintenance through frequent revisions,
- Attainability of targets for continuous waste minimisation and progress of the phased approaches,
- Cost analysis for each waste stream and any proposed new options or techniques.

Integration of plans

Area waste management plans should be compiled into one integrated waste management plan for the Company. Apart from the cost-effective benefits of such integration the plan can be used to develop a regional waste management plan for oil and gas operating companies in a defined area. Such a regional plan could be used for example to establish cooperative waste-disposal sites and combined or joint pretreatment facilities.

Plan reviewal

The plan should be formally reviewed periodically to ensure that all selected options remain current with regulations, technology, and environmental science. New and innovative minimisation, handling and disposal strategies should also be formally reviewed through the 8-step process approach to enhance and improve the original plan as shown in Fig. 1. The review should consider the following issues:

- Any recent changes in the organisation of site management and supervision which could necessitate reassignment of responsibility or authority for implementing the authorised waste disposal practices,
- The local inventory of types and quantities of wastes is up-to-date and any changes in type or quantities of wastes which are likely to occur before the next routine review are identified,
- Currently applied methods for safe disposal of the wastes, to ensure that it is complete, up-to-date with regard to technical description and cost information, and appropriate relative to the latest applicable regulations,
- Each selected method of waste disposal is reviewed in the light of any changed circumstances which may have arisen, or foreseen,
- The availability of local alternative plans for switching to other waste disposal options in case of possible adverse events,
- The appropriateness of continuing with each current method of outside waste disposal in the light of the contractor's performance. This should have particular regard to available reports of the safety and technical adequacy of site waste handling instructions and the current status of training programmes. Waste segregation, sampling, control and recording procedures are understood and implemented, introducing changes where necessary,
- The appropriateness of continuing with each current method of outside waste disposal in the light of the contractor's performance. This should have particular regard to available reports of the safety and technical adequacy of his operations; observance of current

contract conditions; permits and regulatory status; adequacy of documentation and record, and cost relative to acceptable alternative contract operations,

- The information available for on- and off-site operations about potential waste disposal hazards is up-to-date and formally recorded. Review adequacy of site waste handling instructions and the current status of training programmes. Waste segregation, sampling, control and recording procedures are understood and implemented, introducing changes where necessary.

References

1. *Waste Management Guide*
   1989 Shell SP SECC
2. *Recommended Practices for Monitoring and Recording of Effluents and Wastes in E&P operations* October 1989.
3. *Waste Management Guidelines*
   Shell U.K. EXPRO
4. *Waste Reduction*
   Report EP 90-1801, 1990
5. *Treatment and disposal methods for waste chemicals,*
   UNEP, Geneva, 1985
6. *Special Waste Legislation Guide, 1988*
   Ministry of Environment and Parks B.C. Canada.
7. *The Use of OBM cuttings in Brick Manufacturing "Shell Oil"*
   The SIPM Waste Reduction Conference, December 1992, The Hague.
8. *Slag-Mix Mud Conversion Cementing Technology: Reduction of Mud Disposal and Management of Rig-site Drilling Wastes* The SIPM Waste Reduction Conference, December 1992, The Hague.
9. E&P Forum Report No. 2.56/187, Guidelines for the Planning of Downhole Injection programmes for Oil Based Mud Wastes and Associated Cuttings from Offshore Wells, October 1993.

Table 1 : Hazardous characteristics

Substance		Characteristics
1.	Explosives	A substance or article with a mass explosion hazard. A substance with a fragment project hazard, but not a mass explosion hazard. A substance with either a minor blast hazard or a minor projection hazard or both but not a mass explosion hazard. A substance or article which presents no significant hazard. Explosion effects are largely confined to the package. No fragment projections of an appreciable size or range are to be expected.
2.	Gases	A flammable gas A non-flammable, non-toxic, non-corrosive gas A poisonous gas A corrosive gas.
3.	Flammable liquids	Extremely flammable liquid (flash point of less than -18°C) Very flammable liquid (flash point not less than -18°C, but less than 23°C) Moderately flammable liquid (flash point not less than 23°C, but less than 61°C)
4.	Flammable solids, spontaneously combustible and dangerous when wet	A solid which under normal circumstances is readily ignitable and burns persistently; or, which causes or contributes to fire, through friction or from heat retained from manufacturing or processing. A substance liable to spontaneous combustion under normal conditions of transport; or, when in contact with air, liable to spontaneous heating to the point where it ignites. A substance which, on contact with water, emits dangerous quantities of flammable gases or becomes spontaneously combustible on contact with water or water vapour.
5.	Oxidising substanaces & Organic peroxides	A substance which contributes to the combustion of other materials by yielding oxygen or oxidising substances, whether or not the substance itself is combustible. An organic compound that contains the bivalent "-0--0-" structure which is a strong oxidising agent and may be liable to explosive decomposition or is sensitive to heat, shock or friction.

Table 1 : Hazardous characteristics (cont.)

Substance		Characteristics
6.	Poisonous & infectious substances	A solid or liquid that is poisonous through inhalation, by skin contact or ingestion. Organisms that are reasonably believed to be infectious to humans or animals and the toxins of such organisms.
7.	Radioactive materials	Radioactive materials with activity greater than permissible limits issued by the Atomic Energy Establishment.
8.	Corrosive substances	A substance that causes visisble necrosis of the skin or that corrodes steel or non-clad aluminium, or that has a pH less than 2 or greater than 12.5.
9.	Miscellaneous dangerous goods	A substance or product which presents sufficient dangers to warrant regulation, but which cannot be assigned to any other class.

Table 2. Example of sensitivity matrix*

Susceptible to contaminant X	Resource value					Sensitive ecology	
	Drinking water source	Catchment area	Irrigation	Fisheries	Sewage treater	Wildlife	Lakes
Organics:							
Oil	++	++	++	++	++	++	++
Petroleum HC	++	++	+	++	+	+	++
PAHs	++	+	+	++	-	-	+
Phenols	++	++	-	++	++	-	+
Organohalogens	++	++	++	++	++	++	++
Organophosphates	++	++	++	++	++	++	++
Organotins	++	++	++	++	++	++	++
Pesticides	++	++	++	++	++	++	++
Biocides	++	++	++	++	++	++	++
Organosilicones	+	+	+	+	+	+	+
Surfactants	++	-	-	++	++	-	+
EDTA	-	-	-	+	-	-	+
Synthetics	++	++	++	++	++	++	++
Metals and metal compounds:							
Cadmium	++	++	++	++	++	++	++
Mercury	++	++	++	++	++	++	++
Arsenic	++	+	++	+	++	+	+
Chromium	++	+	++	+	++	+	+
Copper	++	+	++	+	++	+	+
Lead	++	+	++	+	++	+	+
Nickel	+	+	++	+	++	+	+
Zinc	++	+	+	++	++	+	+
Antimony	+	+	-	-	-	+	+
Beryllium	+	+	++	-	+	+	+
Selenium	++	+	++	-	++	+	+
Vanadium	+	+	+	-	-	+	+
Molybdenum	+	+	++	-	-	++	+
Tin	-	+	-	+	++	-	+
Cobalt	+	+	++	+	+	+	+
Silver	-	+	-	+	++	-	+
Aluminium	-	-	++	-	+	-	-
Barium	++	+	-	-	++	-	-
Boron	++	+	++	-	++	-	-
Iron	++	-	+	-	++	-	-
Manganese	++	-	++	-	++	-	-
Inorganics:							
acids	+	-	+	+	+	+	+
alkali	+	-	+	+	+	+	+
chloride/salinity	++	+	++	+	++	++	+
fluorides	++	+	+	-	++	+	+
cyanides	++	++	+	+	++	+	+
ammonia	++	+	-	++	+	-	+
nitrates	++	+	-	+	+	-	+
nitrites	+	+	-	++	++	+	+

phosphates	++	+	-	++	++	-	+
H2S/sulphides	+	+	-	+	++	-	+
sulphates	++	+	-	-	++	-	+
active chlorine	++	-	-	++	++	-	+
Other:							
Scrap metal etc	+	-	+	+	+	+	+
Dispersed solids	++	-	+	++	++	-	+
Tainting subst.	++	+	-	+	-	-	+
Radioactive mat.	++	++	++	++	+	++	++
pH	++	-	+	+	++	+	+
BOD	++	-	-	++	++	-	+
COD	+	-	-	+	++	-	+
Temperature	++	-	+	+	++	-	+
Coloration	++	-	-	-	-	-	+
Odour	+	-	-	-	-	-	+
Toxic & persistent	++	++	++	++	++	++	++
++ Black list substance, hazard in all environments, significant impact. + Grey list substance, partially hazard depend on concentration, quantity and proximity. - no impact							

* Ref. 2.

Table 3. Black list and grey list components

BLACK LIST COMPONENTS	
1.	Organo-halogen compounds and substances which may form such compounds in the aquatic environment,
2.	Organo-phosphorous compounds,
3.	Organo-tin compounds,
4.	Substances in respect of which it has been proven that they possess carcinogenic properties in or via the aquatic environment,
5.	Mercury and its compounds,
6.	Cadmium and its compounds,
7.	Persistent mineral oils and hydrocarbons of petroleum origin,
8.	Persistent synthetic substances which may float, remain in suspension or sink and which may interfere with any use of the waters.

GREY LIST COMPONENTS	
1.	1. Zinc 2. Copper 3. Nickel 4. Chromium 5. Lead 6. Selenium 7. Arsenic 8. Antimony 9. Molybdenum 10. Titanium 11. Tin 12. Barium 13. Berryllium 14. Boron 15. Uranium 16. Vanadium 17. Cobalt 18. Thallium 19. Tellurium 20. Silver
2.	Biocides and their derivatives.
3.	Substances which have a deleterious effect on the taste and/or smell of products for human consumption derived from the aquatic environment, and compounds liable to give rise to such substances in water.
4.	Toxic or persistent organic compounds of silicon, and substances which may give rise to such compounds in water, excluding those which are biologically harmless or are converted in water into harmless substances.
5.	Inorganic compounds of phosphorous and elemental phosphorous.
6.	Non-persistent mineral oils and hydrocarbons of petroleum origin.
7.	Cyanides and fluorides.
8.	Substances which have an adverse effect on the oxygen balance, particularly: ammonia, nitrates.

Table 4. Waste treatment processes

Chemical treatment

- Neutralisation of acids and alkalies
- Extraction of toxic metals
- Redox process to convert hazardous metals to non-hazardous
- Solidification of liquid waste by cement, polymer

Physical treatment

- Evaporation
- Filtration
- Sedimentation
- Carbon absorption
- Encapsulation

Thermal treatment

- Controlled incineration
- Smelting
- Burning

Biological treatment

- Microbial
- Biodegradation

Table 5. Current treatment technologies for produced water

Technologies	Advantages	Disadvantages	Capability
Gas flotation	• Well known with long operating history • Independent on differential density between oil and water • Effective for removing oil emulsion when chemically assisted	• Vulnerable to operational change • Sensitive to flow rate and composition of water • Sensitive to chemical dosing • Highly overhead • Heavy and bulky hardware	Can achieve oil-in-water concentration 30-60 mg/l with average of 40 mg/l
Static hydrocyclones	• Light weight and compact • High efficiency for disposed oil removal • Easy to operate and maintain • Insensitive to slugging • Easily expandable	• Highly dependent on differential density between oil and water • Will not remove emulsified oil without chemical addition	Can achieve average concentration below 30 mg/l
Media filters/coalescers	• Removes both emulsified and dispersed oil	• Heavy and bulky equipment • Not useable with waxy crudes • Subject to plugging by particulates	Can achieve 30 mg/l depending on efficiency of water back wash
Membrane filtration	• Remove both emulsified and dispersed oil • Simple components	• Low volumetric flux rates • Require large recycle flow and high power consumption • Sensitive to feed stream characteristics and chemical dosage	Will reach maturity within 3-5 years with capabilities of 20-30 mg/l

ANNEX 1 Typical Wastes, Main Components And Environmentally Significant Constituents From E&P Activities

1. Activity : Seismic

Type of waste	Main components	Possible environmentally significant constituents
Domestic		
Domestic sewage	Biodegradable organic matter	BOD, solids, detergent, coliform bacteria
Domestic refuse	Packing materials, cleaning materials, garbage, garden leftovers, kitchen waste	Plastics, glass, organic waste
Industrial		
Drilling Chemical Fluids	Natural clays natural polymers (starches,carboxy methyl cellulose)	-
Waste lubricants	Lube oil, grease	Organics, heavy metals
Industrial refuse	Scrap iron/wires, cleaning materials, packing materials	Heavy metals, metals, plastics
Exhaust gases from engines		NO_X, SO_2, CO_X, carbon particulates
Energy sources	Batteries	Acid, heavy metals

2. Activity : Drilling

Type of waste	Main components	Possible environmentally significant constituents
Domestic		
Domestic sewage	Biodegradable organic matter	BOD, solids, detergent, coliform bacteria
Domestic refuse	Packing materials, cleaning materials, garbage, garden leftovers, kitchen waste	Plastics, glass, organic waste
Industrial		
Drainage	Rainwater	Hydrocarbons
Process water	Engine cooling water, brake cooling water, wash water	Hydrocarbons Detergents
Gases	Vent gases Flare gases Blowdown from bulk chemicals Vapours	H_2S, CO_2, hydrocarbons NO_x, SO_2, CO_x, carbon particulate Dust, well fluids Hydrocarbons
Fire fighting agents		CFC's, Halons
Waste lubricants	Lube oil, grease	Heavy metals, organics
Spacers	Mineral oil, detergents, surfactants	Hydrocarbon, alcohol, aromatics
Cement slurries Cement mix water	Weighting materials, salts, thinners, viscosifiers	Heavy metals Heavy metals
Spent/contaminated water based muds (include brine)	Whole mud, mineral oil Biodegradable matter	Heavy metals, inorganic salts, biocides, hydrocarbons solids/cutting, BOD, organics
Water based muds cuttings	Formation solids, water based muds mineral oil	Heavy metals, inorganic salts, biocides, hydrocarbons, solids/cutting,
Spent/contaminated oil based muds	Whole mud mineral oil	Hydrocarbons, heavy metals, inorganic salts, solids, BOD, organics, surfactants
Oil based muds cuttings	Formation solids, oil based muds	Heavy metals, inorganic salts, hydrocarbons, solids/cutting,

2. Activity : Drilling (continued)

Type of waste	Main components	Possible environmentally significant constituents
Spent bulk chemicals	Cement, bentonite, barytes, viscosities, thinners, fluid loss reducers, speciality products	Heavy metals, hydrocarbons, organics, solids
Spent specialty products	H_2S scavengers Defoamers Tracers	Zinc carbonates, iron oxides hydrocarbons, silicon oils, potassium salts, radioactive materials
Industrial refuse	Scrap, cleaning materials, packing materials	Heavy metals, metals, plastics
Energy sources	Batteries	Acid, heavy metals

3. Activity : Well treatment

i.e. completion, stimulation, squeezes, fracturing, consolidation, etc.

Type of waste	Main components	Possible environmentally significant constituents
Domestic		
Domestic sewage	Biodegradable organic matter	BOD, solids, detergent, coliform bacteria
Domestic refuse	Packing materials, cleaning materials, garbage, garden leftovers, kitchen waste	Plastics, glass, organic waste
Industrial		
Spent completion fluids	Whole fluids	Inorganic salts, hydrocarbons, corrosion inhibitors
Spent/returned stimulation fluids	Inorganic acids, spacers, formation fluids, gas oil	HCl, HF, hydrocarbons, methanol, corrosion inhibitors, scavengers formation fluids, radioactive scale
Squeeze fluids	Scale inhibitors, corrosion inhibitors	Organic polyphosphates, organic amines
Fracturing fluids	Whole fluids, gas oil	Hydrocarbons, gelling agents
Consolidation materials	Carrier fluids, epoxy resins	Hydrocarbons
Sand from wells	Sand, oil	Hydrocarbons
Industrial refuse	Scrap, cleaning materials, packing materials	Heavy metals, metals, papers, plastics
Energy sources	Batteries	Acid, heavy metals

4. Activity : Oil production

Type of waste	Main components	Possible environmentally significant constituents
Domestic		
Domestic sewage	Biodegradable organic matter	BOD, solids, detergent, coliform bacteria
Domestic refuse	Packing materials, cleaning materials, garbage, garden leftovers, kitchen waste	Plastics, glass, organic waste
Industrial		
Production water	Formation fines, production chemicals, oils, biodegradable organic matter	Inorganic salts, heavy metals, solids, organics, BOD, sulphides, corrosion inhibitors, demulsifiers, wax inhibitors, scale inhibitors, biocides, radioactive mat., hydrocarbons, phenols, PAH, organohalogens
Process water	Formation fines, production chemicals, oils, biodegradable organic matter	Inorganic salts, heavy metals, solids, organics, BOD, sulphides, corrosion inhibitors, demulsifiers, wax inhibitors, scale inhibitors, biocides, detergent, hydrocarbons
Contaminated/rain drainage water	Formation fines, production chemicals, oils, biodegradable organic matter	Inorganic salts, heavy metals, solids, organics, BOD, sulphides, corrosion inhibitors, emulsifiers, wax inhibitors, scale inhibitors, biocides, detergent, hydrocarbons
Ballast water		Hydrocarbons, phenols, PAH
Vent gases		Natural gases, H_2S, CO_2
Exhaust gases, flare gases		CO_2, NO_x, SO_2, carbon, CO
Fugitive gases		Volatile organic compounds (VOC)
Fire fighting agents		Halons
Refrigerants		CFC's

4. **Activity : Oil production** (continued)

Type of waste	Main components	Possible environmentally significant constituents
Tank sludges/scale	Formation fines, production chemicals, oils, biodegradable organic matter	Inorganic salts, heavy metals, solids, organics, BOD, sulphides, corrosion inhibitors, demulsifiers, wax inhibitors, scale inhibitors, biocides, radioactive mat., hydrocarbons, phenols, PAH
Pigging sludges	Formation fines, production chemicals, oils, biodegradable organic matter	Inorganic salts, heavy metals, solids, organics, BOD, sulphides, corrosion inhibitors, demulsifiers, wax inhibitors, scale inhibitors, biocides, radioactive mat., hydrocarbons, phenols, PAH
Spent production chemicals		Demulsifiers, corrosion inhibitors, wax inhibitors, scale inhibitors, anti-foaming agents, oxygen scavengers, biocides
Waxes	Corrosion products oil	Production chemicals, hydrocarbons, asphalthenes, wax
Industrial refuse	Scrap, cleaning materials, packing materials	Heavy metals, metals, plastics
Industrial waste	Batteries	Acid, heavy metals
Hospital waste.	Dressing, clinical & cleaning materials, blood samples.	Pathogenic organisms, plastic, glass, medicines.

5. Activity : Gas production

Type of waste	Main components	Possible environmentally significant constituents
Domestic		
Domestic sewage	Biodegradable organic matter	BOD, solids, detergent, coliform bacteria
Domestic refuse	Packing materials, cleaning materials, garbage, garden leftovers, kitchen waste	Plastics, glass, organic waste
Industrial		
Production water	Formation fines, production chemicals, oils, biodegradable organic matter	Inorganic salts, heavy metals, solids, organics, BOD, sulphides, corrosion inhibitors, demulsifiers, scale inhibitors, radioactive mat., hydrocarbons, phenols, PAH, organohalogens
Contaminated/rain drainage water	Formation fines, production chemicals, oils, biodegradable organic matter	Inorganic salts, heavy metals, solids, organics, BOD, sulphides, corrosion inhibitors, demulsifiers, scale inhibitors, detergent, hydrocarbons
Process water	Formation fines, production chemicals, oils, biodegradable organic matter	Inorganic salts, heavy metals, solids, organics, BOD, sulphides, corrosion inhibitors, demulsifiers, scale inhibitors, detergent, hydrocarbons
Ballast water		Hydrocarbons, phenols, PAH
Vent gases	Natural gases, H_2S, CO_2	
Exhaust gases, flare gases	CO_2, NO_x, SO_2, carbon	
Fugitive gases		Volatile organic compounds (VOC)
Firefighting agents	Halons	Halons
Refrigerants	CFC's	CFC's
Tank sludges	Formation fines, production chemicals, oils, biodegradable organic matter	Inorganic salts, heavy metals, solids, organics, BOD, sulphides, corrosion inhibitors, demulsifiers, scale inhibitors, radioactive mat., hydrocarbons, phenols, PAH

5. Activity: Gas production (continued)

Type of waste	**Main components**	**Possible environmentally significant constituents**
Pigging sludges	Formation fines, production chemicals, oils, biodegradable organic matter	Inorganic salts, heavy metals, solids, organics, BOD, sulphides, corrosion inhibitors, demulsifiers, scale inhibitors, radioactive mat., hydrocarbons, phenols, PAH
Spent production chemicals		Demulsifiers, corrosion inhibitors, scale inhibitors, anti-foaming agents, oxygen scavengers
Waxes	Corrosion products	Production chemicals, hydrocarbons, asphalthenes
Industrial refuse	Scrap, cleaning materials, packing materials	Heavy metals, metals, plastics
Industrial waste	Batteries	Acid, heavy metals
Hospital waste.	Dressings, clinical & cleaning materials, blood samples.	Pathogenic organisms, plastic, glass, medicines.

6. Activity : Construction & commissioning

Type of waste	Main components	Possible environmentally significant constituents
Domestic		
Domestic sewage	Biodegradable organic matter	BOD, solids, detergent, coliform bacteria
Domestic refuse	Packing materials, cleaning materials, garbage, garden leftover, kitchen waste	Plastics, glass, organic waste
Industrial		
Hydrotest fluids	Biocides, corrosion inhibitors, oxygen scavengers, tracers, dyes	BOD, solids, biocides, corrosion inhibitors, oxygen scavengers, dyes
Fugitive gases		Volatile organic compounds (VOC)
Fire fighting agents	Halons	Halons
Refrigerants	CFC's	CFC's
Drying fluids	Corrosion products, oils, drying agents	Glycols, hydrocarbons
Construction materials	"Sandblast" (grits), paints, thinners, greases, fuel oils	Heavy metals, hydrocarbons, solids
Scrap metals	Various steel alloys, electrical cables, empty drums.	Heavy metals, metals
Industrial refuse	Scrap, cleaning materials, packing materials	Heavy metals, metals, plastics
Industrial waste	Batteries	Acid, heavy metals
Hospital waste.	Dressings, clinical & cleaning materials, blood samples.	Pathogenic organisms, plastic, glass, medicines.

7. Activity: Maintenance

Type of waste	Main components	Possible environmentally significant constituents
Domestic		
Domestic sewage	Biodegradable organic matter	BOD, solids, detergent, coliform bacteria
Domestic refuse	Packing materials, cleaning materials, garbage, garden leftovers, kitchen waste	Plastics, glass, organic waste
Industrial		
Fugitive gases		Volatile organic compounds (VOC)
Fire fighting agents	Halons	Halons
Refrigerants	CFC's	CFC's
Wash fluids	Biodegradable organic matter, cleaning agents, oils	Detergents, surfactants, BOD, solids, hydrocarbons
Paint materials	Paints, thinners, coating	Heavy metals, solvent, hydrocarbon
Scrap metals	Various steel alloys, electrical cables, empty drums.	Heavy metals
Industrial refuse	Scrap, cleaning materials, packing materials	Heavy metals, metals, plastics
Industrial waste	Batteries	Acid, heavy metals
Hospital waste.	Dressings, clinical & cleaning materials, blood samples.	Pathogenic organisms, plastic, glass, medicines.

8. Activity: Abandonment

Type of waste	Main components	Possible environmentally significant constituents
Domestic		
Domestic sewage	Biodegradable organic matter	BOD, solids, detergent, coliform bacteria
Domestic refuse	Packing materials, cleaning materials, garbage, garden leftovers, kitchen waste	Plastics, glass, organic waste
Industrial		
Fugitive gases		Volatile organic compounds (VOC)
Fire fighting agents	Halons	Halons
Refrigerants	CFC's	CFC's
Clean-up process equipment	Formation fines, production chemicals, oils, sludges, biodegradable organic matter	Inorganic salts, heavy metals, solids, organics, BOD, sulphides, corrosion inhibitors, demulsifiers, wax inhibitors, scale inhibitors, detergents, biocides, radioactive mat., PCB, hydrocarbons, phenols, PAH
Used pipeline	Metals	
Used process equipment	Various steel alloys	
Abandoned platform	Metals	
Industrial refuse	Scrap, cleaning materials, packing materials	Heavy metals, metals, plastics
Industrial waste.	Batteries ,transformers.	Acid, heavy metals, PCB's.

ANNEX 2

A. POINTS TO BE CONSIDERED FOR WASTE MINIMISATION

1. Take all technically and economically viable measures to minimise generation of waste through process optimisation. Scan for the following:
   - Formation water re-injection or re-use
   - Use of waste heat
   - Improving efficiency of power generation
   - Improve combustion efficiency, flare stability
   - Recycling mud systems
2. Review the points at which waste can arise (from both new and existing installations), including unwanted products of a chemical reaction.
3. Critically examine processes generating the most significant amounts of waste (consider e.g., alternative raw materials)
4. Review any process where the conversion efficiency deviates greatly from that expected.
5. Look for high calorific wastes that can be used to support combustion of less combustible materials.
6. Periodically check the amount of waste generated against the target.
7. Carry out regular inspection and maintenance of installation to limit mechanical failures which are a source of incidental waste generation.
8. Establish start-up and shut-down procedures that minimise the quantity of waste and off-grade products generated.
9. Provide equipment clean-out procedures that minimise waste generation and consider collection of solvents or other materials for regeneration and re-use.
10. Practice good housekeeping and segregation of waste streams - these will generally lead to waste reduction.
11. When changing over to other raw materials, products or chemicals, make sure that old stocks have been utilised or depleted.
12. Do not over-order raw materials.
13. Regularly check warehouses for unused products and arrange useful outlets.

B. Examples of options for special wastes minimisation and disposal

Special waste type	Options
Acids and alkalis	• recycling • neutralisation
Asbestos	• solidification • containment during transport • landfill
Chromium	• recycling • chemical reduction of trivalent state • physical/chemical treatment • solidification and secure landfill
Cyanides	• recycling • chemical oxidation • physical/chemical treatment • solidification and secure landfill • high temperature incineration
Fluorides	• physical/chemical treatment • solidification and secure landfill
Heavy metal waste	• recycling • physical/chemical treatment • solidification and secure landfill
Infectious waste	• biological treatment • thermal destruction • chemical disinfection
Oils	• recycling • physical/chemical treatment • biological treatment • incineration
Organic waste (halogenated)	• recycling • physical/chemical treatment • high temperature incineration
Organic wastes (non halogenated)	• recycling • biological treatment • physical/chemical treatment • incineration
Pesticides	• biological treatment • physical/chemical treatment • high temperature incineration
Sulphides	• physical/chemical treatment • chemical oxidation