

Environmental Guidance Document: Waste Management in Exploration and Production Operations

API E5
SECOND EDITION, FEBRUARY 1997



STEP

One of the most significant long-term trends affecting the future vitality of the petroleum industry is the public's concerns about the environment. Recognizing this trend, API member companies have developed a positive, forward looking strategy called STEP: Strategies for Today's Environmental Partnership. This program aims to address public concerns by improving industry's environmental, health and safety performance; documenting performance improvements; and communicating them to the public. The foundation of STEP is the API Environmental Mission and Guiding Environmental Principles. API standards, by promoting the use of sound engineering and operational practices, are an important means of implementing API's STEP program.

API ENVIRONMENTAL MISSION AND GUIDING ENVIRONMENTAL PRINCIPLES

The members of the American Petroleum Institute are dedicated to continuous efforts to improve the compatibility of our operations with the environment while economically developing energy resources and supplying high quality products and services to consumers. The members recognize the importance of efficiently meeting society's needs and our responsibility to work with the public, the government, and others to develop and to use natural resources in an environmentally sound manner while protecting the health and safety of our employees and the public. To meet these responsibilities, API members pledge to manage our businesses according to these principles:

- To recognize and to respond to community concerns about our raw materials, products and operations.
- To operate our plants and facilities, and to handle our raw materials and products in a manner that protects the environment, and the safety and health of our employees and the public.
- To make safety, health and environmental considerations a priority in our planning, and our development of new products and processes.
- To advise promptly appropriate officials, employees, customers and the public of information on significant industry-related safety, health and environmental hazards, and to recommend protective measures.
- To counsel customers, transporters and others in the safe use, transportation and disposal of our raw materials, products and waste materials.
- To economically develop and produce natural resources and to conserve those resources by using energy efficiently.
- To extend knowledge by conducting or supporting research on the safety, health and environmental effects of our raw materials, products, processes and waste materials.
- To commit to reduce overall emissions and waste generation.
- To work with others to resolve problems created by handling and disposal of hazardous substances from our operations.
- To participate with government and others in creating responsible laws, regulations and standards to safeguard the community, workplace and environment.
- To promote these principles and practices by sharing experiences and offering assistance to others who produce, handle, use, transport or dispose of similar raw materials, petroleum products and wastes.

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Exploration and Production Department

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FOREWORD

This document reflects our industry's continuing commitment to environmental protection. It provides guidance for minimizing the direct and indirect environmental impacts of solid wastes originating from typical exploration and production (E&P) activities, which include exploration, drilling, well completions and workovers, field production, and gas plant operation.

This manual was prepared by the API Production Waste Issues Group, under the jurisdiction of the API Exploration and Production Department Executive Committee on Environmental Conservation.

The oil and gas industry must operate where oil and gas deposits are found. This means that the exploration and production activities listed above will be conducted in a variety of ecosystems, whose sensitivity to the activities of man will vary widely. The oil and gas industry must be environmental stewards in two critical ways:

- a. It must use environmentally sound operating practices to manage materials, land, and the waste generated from exploration and production activities.
- b. It must produce oil and gas reserves as efficiently and prudently as possible in order to prevent squandering critical natural resources.

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Suggested revisions are invited and should be submitted to the director of the Exploration and Production Department, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005.

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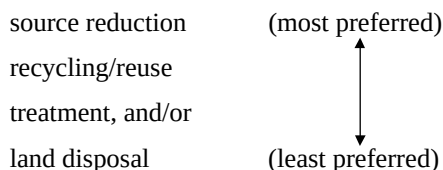
Waste Management in Exploration and Production Operations

1 Pollution Prevention

1.1 INTRODUCTION

Pollution prevention is the practice of reducing or eliminating pollutant discharges to air, water, or land. It includes the development of more environmentally acceptable products, changes in processes and practices, source reduction, beneficial use, environmentally sound recycling, waste minimization, proper waste handling, waste treatment, and proper disposal practices. This section presents an overview of media, operational impacts, and waste minimization methods, including the EPA hierarchy of waste management. These basic concepts are critical in achieving pollution prevention goals.

Pollution prevention requires continuous improvement in operating practices. Industry should review its use of materials, processes, practices, and products in order to identify ways to reduce or eliminate pollution. A practical approach encourages the use or production of environmentally acceptable products while working toward source reduction on the following waste management hierarchy:



Details are presented in 1.3.2.

The API Pollution Prevention Management Practices for API's Strategies for Today's Environmental Partnerships (STEP) program embody the petroleum industry's practical commitment to pollution prevention. They provide specific guidelines for compliance with these Guiding Environmental Principles, which are as follows:

- To recognize and to respond to community concerns about our raw materials, products, and operations.
- To operate our plants and facilities, and to handle our raw materials and products in a manner that protects the environment and the safety and health of our employees and the public.
- To make safety, health, and environmental considerations a priority in our planning, use, and development of new products and processes.
- To advise promptly appropriate officials, employees, customers, and the public of information on significant industry-related safety, health, and environmental hazards and to recommend protective measures.
- To counsel customers, transporters, and others in the safe use, transportation, and disposal of our raw materials, products, and waste materials.
- To develop and produce natural resources economically and to conserve those resources by using energy efficiently.
- To extend knowledge by conducting or supporting research on the safety, health, and environmental effects of our raw materials, products, processes, and waste materials.
- To commit to reduce overall emissions and waste generation.
- To work with others to resolve problems created by handling and disposal of hazardous substances from our operations.
- To participate with government and others in creating responsible laws, regulations, and standards to safeguard the community, workplace, and environment.
- To promote these principles and practices by sharing experiences and offering assistance to others who produce, handle, use, transport, or dispose of similar raw materials, petroleum products, and wastes.

1.2 API'S MANAGEMENT PRACTICE FOR POLLUTION PREVENTION

Both management commitment and comprehensive planning are critical to a successful pollution prevention program. Steps to consider in developing and operating such a program include the following:

- Providing management support for ongoing pollution prevention activities through appropriate policies, actions, communications, and resource commitments.
- Developing and implementing a program to improve prevention and early detection and reduce impacts of spills of crude oil and petroleum products and other accidental releases from operations.
- Developing an inventory of significant releases to air, water, and land; identifying their sources; and evaluating their impact on human health and the environment.
- Periodically reviewing and identifying pollution prevention options and opportunities, developing approaches for reducing releases, and setting goals and schedules for reducing releases and measuring progress; consider the issues of community concerns, technology and economics, and impact on human health and the environment.
- Including pollution prevention objectives in research efforts and in the design of new or modified operations, processes, and products.
- Supporting an outreach program to promote pollution prevention opportunities within the industry, including sharing of industry experiences and accomplishments.

1.3 MEDIA

Proper management of wastes is important to the protection of human health and the environment. Waste can be transported via three natural carriers—water, soil, and air.

All three media may provide pathways by which potentially polluting materials can migrate from their original source. Thus, materials used and wastes generated in exploration and production operations should be managed by considering risk to human health and the environment via media pathways (see Figure 1).

1.3.1 Water

Fresh water for human consumption, domestic needs, recreation, stock water, irrigation of crops, and industry comes from underground aquifers, lakes, streams, and reservoirs.

Most fresh water is stored in underground reservoirs called aquifers. Aquifers are part of a large water-recycling system as illustrated in Figure 1. These porous formations or sediments can store and transport groundwater from rain, leakage of stream beds, and other sources.

Materials from spills or improper waste disposal may contaminate aquifers. Of major concern are those aquifers that contain water suitable for drinking. Also important are aquifers used for agricultural purposes. Pollutants found in water are measured in concentrations of parts per billion (ppb); some of these pollutants may cause that water to fail drinking water standards.

The quality of aquifer waters can be degraded by pollutants to such a degree that it is not practical to restore the aquifer to drinking water standards.

1.3.2 Soil

Spills can adversely affect the capacity of soil to support agricultural, industrial, human, and recreational uses. Soil acts to retain spilled, improperly stored, or disposed materials; however, once in the soil, pollutants can migrate to air and water and be picked up by plants and animals. Contam-

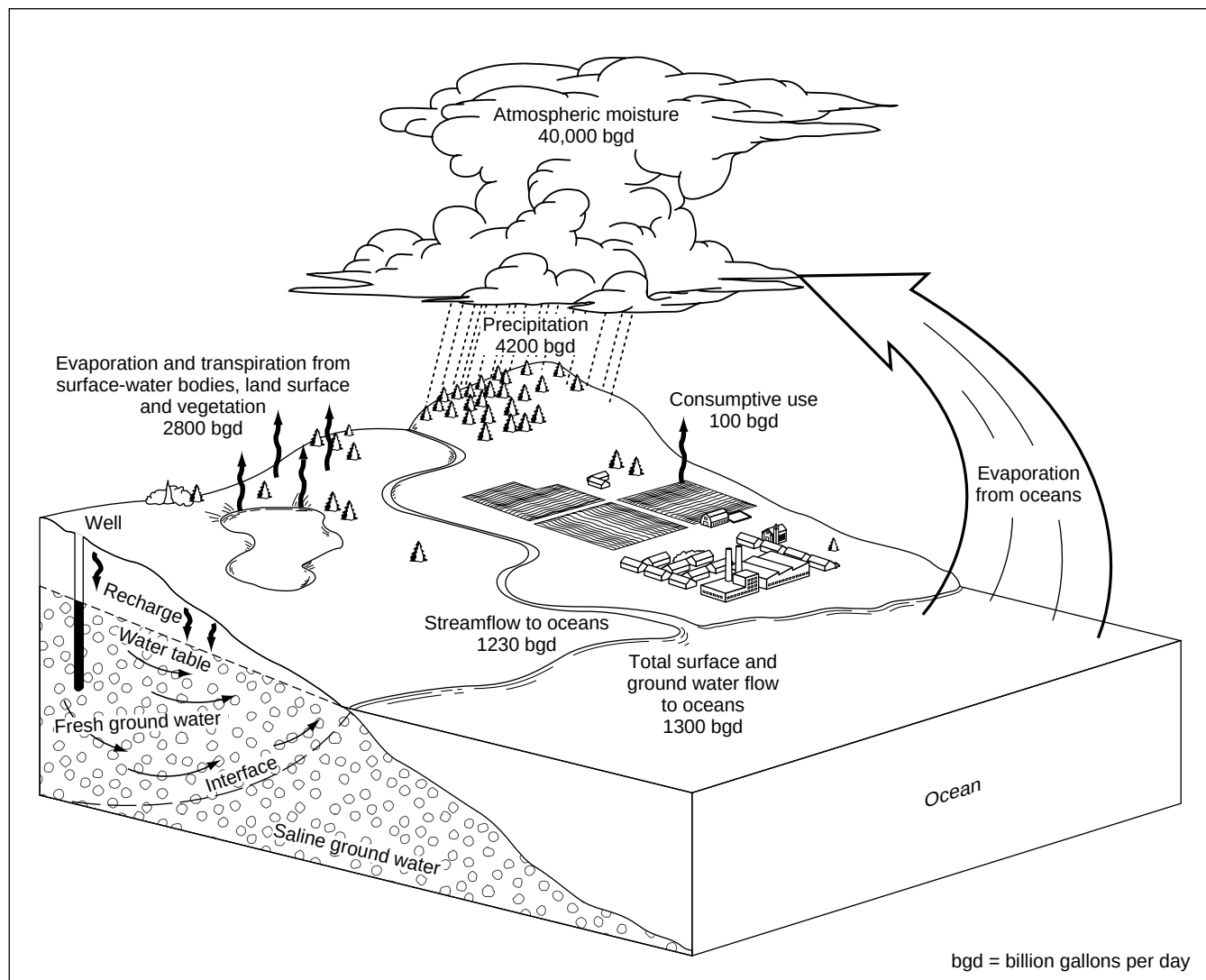


Figure 1—Basic Media of Soil, Air, and Water Can Transport Pollutants Away From Their Original Source

inants can evaporate into the atmosphere, be carried by rain-water to a lake, creek, or other surface water, and be leached downward into groundwater.

1.3.3 Air

Gaseous waste released to the air can potentially affect humans, animals, and plant life through inhalation or dermal contact. Indirectly, gaseous wastes may alter the chemical balance in the atmosphere. Acid rain is a known result of altering the chemical makeup of the atmosphere. Ozone depletion and global warming are thought by some to be the result of human impact on the atmosphere.

1.3.4 Summary

A properly implemented pollution prevention program can reduce or eliminate pollutant discharges to air, water, or land. API supports cooperative efforts to research and develop scientifically based standards and promotes technical advancements for the evaluation and implementation of measures to address environmental impacts.

1.4 UNDERSTANDING OPERATIONAL IMPACTS

Because exploration and production (E&P) operations can affect all environmental media, API suggests the use of sound science to identify adverse impacts and the means to mitigate, reduce, or eliminate them. Science is also critical to developing cost-effective strategies that address environmental risks. Science provides the foundation for identifying methods to prevent or reduce pollution, for expanding waste management options to reduce risk, and for developing and improving pollution control technologies.

Sound science is the key to determining which environmental problems pose the greatest risk to human health, ecosystems, and the economy. Without sound scientific information, high profile but low risk problems may possibly be targeted, while more significant threats remain ignored.

A sound scientific understanding of environmental risks to populations and ecosystems will help create a more effective allocation of resources—resources which can be targeted towards hazards that pose the greatest environmental risk.

1.5 POLLUTION PREVENTION AND WASTE MINIMIZATION

Waste minimization is a major component of pollution prevention. The goals of a waste minimization plan are to reduce the total volume or quantity of waste generated and to reduce the toxicity of waste.

Hydrocarbon recovery, an extractive procedure, inherently generates wastes. Some of these wastes are similar to those

generated by the general public and can be managed similarly. Most of the waste generated by the oil and gas industry consists of naturally occurring materials brought to the surface in association with extracted oil and gas.

Due to large increases in costs of waste management, increasing complexity of waste management regulations, and efforts to reduce potential environmental liabilities, many API member companies have implemented in-house waste minimization programs.

These programs go beyond traditional approaches to waste management and incorporate pollution prevention concepts.

1.5.1 Solid Waste Definition

According to federal regulations, a solid waste is any material that is discarded or intended to be discarded. Solid wastes may be either solid, semi-solid, liquid, or contained gaseous material. Point source water discharges, subject to federal permits under the Clean Water Act, are not considered solid wastes.

1.5.2 EPA Hierarchy of Methods

EPA has developed the following hierarchy of waste management methods to guide generations toward waste minimization. The four waste management hierarchy steps, in decreasing order of preference are as follows:

- a. Source Reduction—reduce the amount of waste at the source through the following:
 - material elimination
 - inventory control and management
 - material substitution
 - process modification
 - improved housekeeping
 - return of unused material to supplier
- b. Recycling/Reuse—reuse and recycle material for the original or some other purpose, such as materials recovery or energy production; this may occur onsite or offsite, through the following methods:
 - reuse
 - reprocess
 - reclaim
 - use as fuel
 - underground injection for enhanced recovery
 - roadspreading
- c. Treatment—destroy, detoxify, and neutralize wastes into less harmful substances through the following methods:
 - filtration
 - chemical treatment
 - biological treatment
 - thermal treatment
 - extraction

- chemical stabilization
- incineration
- landfarming
- landspreading

d. Disposal—dispose of wastes through the following methods:

- landfills
- NPDES discharge
- solidification
- burial
- underground injection for disposal

1.5.3 Summary

By incorporating waste minimization practices into the waste management program, the generator may further efforts to

- Protect public health and worker health and safety.
- Protect the environment.
- Meet company, state, and/or national waste minimization goals.
- Save money by reducing waste treatment and disposal costs and other operating costs.
- Reduce potential environmental liabilities.

2 Waste Management System

2.1 INTRODUCTION

In order to achieve pollution prevention and waste minimization goals, waste management needs to be viewed as an integrated system. A good waste management system should include the following key elements:

- A system for maintaining knowledge of pertinent laws and regulations.
- A system for pollution prevention/waste minimization.
- A health and safety program.
- An incident response preparedness program.
- A training program.
- A system for proper waste identification.
- A transportation program.
- A proper waste storage and disposal program.
- A system for waste tracking, inventories, and record-keeping.
- A waste management auditing program.

This section introduces the concept of a waste management plan—the tool for implementing these key elements at the field level, where actual waste management decisions should be made.

The key elements of training, waste tracking, and auditing are also discussed.

2.2 SUMMARY OF A TEN-STEP PLAN FOR WASTE MANAGEMENT

A waste management plan should

- Offer a solid waste plan that is area-specific.
- Provide proper management guidance for each waste generated in E&P operations.
- Be written for field operations.
- Be used to ensure regulatory compliance and environmentally sound management of wastes.
- Form a basis for training, evaluation, monitoring, and pollution prevention programs.
- Be periodically reviewed and updated as new practices and options are discovered.

API suggests the ten-step waste management plan shown in Table 1 for integrating the waste management system into operations. This plan is described in detail in Appendix A. It has proven successful for a number of member companies. Appendix B includes planning aids to help in preparing the waste management plan.

Both technology and regulatory requirements in the environmental field are changing constantly. For these reasons, open communication among field operations personnel, environmental and legal specialists, and management is crucial to conducting environmentally sound operations.

2.3 TRAINING

Training in the proper identification and handling of waste material is vital in any exploration or production operation. Field personnel and management should be trained in environmentally sound and safe waste management practices. Instruction in waste management should include the following:

- General environmental awareness.
- Health and safety concerns related to waste handling.
- Benefits of proper waste management, including risk reduction for future liabilities.
- Review of internal environmental policies and other documentation of management support.
- Environmental laws and regulations.
- Legal liability, both corporate and personal, associated with improper handling of waste.
- The applicable facility waste management program.

In addition, a company may consider scheduling periodic training to cover updates of procedures, review of incidents, and feedback from field personnel.

Federal agencies also mandate personnel training as follows:

- The U.S. Occupational Safety and Health Administration (OSHA) requires specific, detailed training for certain operations that may be associated with waste management.
- Emergency response to a release of hazardous chemicals

(including crude oil) and the following cleanup operations may require certified and trained personnel (HAZWOPER—29 *Code of Federal Regulations* Part 1910.120).

c. OSHA also has training and information requirements for personnel who might be exposed to hazardous chemicals (HAZCOM—29 *Code of Federal Regulations* Part 1910.1200).

d. The EPA requires annual training for certain hazardous waste generators (40 *Code of Federal Regulations* Part 262.34).

e. State agencies may have additional health, safety, and waste management requirements.

f. The U.S. Department of Transportation (DOT) and some state agencies have transportation requirements for certain wastes. Specific training is required for employees handling hazardous materials (49 *Code of Federal Regulations* Part 172.702).

Training can be done in-house or through enrollment in schools, workshops, seminars, and conferences available to industry and the general public. Many training opportunities are available through academic institutions or private companies.

2.4 WASTE TRACKING

To ensure proper waste disposal and to minimize individual company liability for the cleanup of improperly disposed waste, it is important to know the types and amounts of waste generated, as well as the ultimate disposition of that waste.

This should be documented by using a company waste tracking system.

Sound waste management techniques should include tracking for both onsite and offsite disposal.

Identification of types and amounts of waste generated ben-

efits operations by allowing identification of waste minimization opportunities. Tracking wastes offsite helps prevent significant costs associated with improper waste disposal.

2.5 AUDITING

Companies should consider developing audit programs for their own facilities as well as third-party facilities that may accept their wastes.

2.5.1 Company Facilities

An onsite waste management auditing program assesses the compliance status of a company's facilities and programs for waste management. An auditing program's goal is to help companies achieve higher levels of environmental performance.

Penalties for noncompliance are harsh. Failure to comply with laws and regulations regarding waste management can subject a company to loss of business opportunities, as well as to civil and criminal penalties. Noncompliance can also subject directors, officers, and employees to fines, criminal penalties, and imprisonment.

One of the benefits of a waste management audit program is that company management is provided with information on waste management practices. Other potential benefits include the following:

- a. Improved compliance records and reduction of fines, legal actions, and incidents or accidents.
- b. Improved communication between all levels of company management.
- c. Improved financial planning efficiency by reducing civil and criminal exposure, enhancing evidence of insurability, im-

Table 1—Ten-Step Plan Summary

Step 1.	Management approval—obtain management approval and support.
Step 2.	Area definition—define operating area such as oil field, unit, lease, or state.
Step 3.	Waste identification—identify each waste generated within Step 2 area and briefly describe each waste.
Step 4.	Regulatory analysis—complete reviews of relevant federal, state, and local laws on waste types for which requirements exist; also review lease agreements and landowner agreements.
Step 5.	Waste classification—categorize each identified waste; determine whether it is “exempt” or “nonexempt” and “nonhazardous” or “hazardous.”
Step 6.	Waste minimization—review processes that generate the waste and execute procedures to reduce waste generation.
Step 7.	List and evaluate waste management and disposal options—list the potential options for each waste and rank their desirability.
Step 8.	Select preferred waste management practice(s)—select a waste management option for each waste and the best practice for each operation location.
Step 9.	Prepare and implement an area-specific waste management plan—develop and implement this by compiling all options into a plan. Summarize in documents.
Step 10.	Review and update waste management plan—Define a review and update procedure.

proving public relations, and reducing barriers to successful acquisitions and merger negotiations.

Refer to the API document *Environmental Audit Guideline Protocol and Checklist* for help in designing an environmental audit format customized to meet the specific criteria of your facility or compliance program. This guideline was developed by API specifically for the oil and gas E&P industry.

2.5.2 Offsite Noncompany Facilities

An integral part of a waste management program should be a system or process to assess whether commercial waste disposal facilities—including reclaiming and recycling facilities to which wastes are sent—operate in an environmentally and financially sound manner. It is imperative to select commercial facilities that manage wastes properly, inclusive of recycling, treatment or neutralization, and disposal. Companies should consider auditing commercial facilities to limit potential exposure to future environmental liability that might result from improper management by the commercial facility.

Commercial disposal site audits should consider the following:

- a. The regulatory aspects of a facility, including:
 1. Proper permits.
 2. Compliance with permits.
 3. Relationship with regulatory agencies.
 4. History of violations.
 5. Remediation projects in progress.
 6. Closure plans.
 7. Insurance or other surety bonds.
 8. Manifesting records and procedures.
- b. The operational aspects of a facility, including:
 1. Adequacy of onsite waste treatment equipment.
 2. Adequacy of disposal or recycling processes.
 3. Location of the disposal of secondary waste streams that the facility is permitted to manage.
 4. Site security.
 5. Adequacy of lab analysis.
 6. Incoming waste testing and verification procedures.
 7. Secondary containment and spill prevention.
 8. Adequate waste storage prior to disposal.
 9. Housekeeping.
 10. Adequate contingency plans and training.
 11. Environmental expertise and financial standing.
- c. Physical aspects, including:
 1. Depth to groundwater.
 2. Monitoring well data.
 3. Soil data.
 4. Geology.
 5. Hydrogeology.
 6. Remoteness of site location and public exposure potential.

Decision criteria that will rate a commercial facility as either acceptable or unacceptable, based on the collected site information, should be established.

Unacceptable sites should not be utilized for waste disposal or recycling.

Site reevaluation on a periodic basis is critical to ensuring that acceptable sites continue to operate acceptably.

3 Waste Generation in Exploration and Production Operations

3.1 INTRODUCTION

Wastes are generated in each phase of E&P operations. This section summarizes wastes generated in each phase and the associated environmental impact considerations. The work phases are as follows:

- a. Exploration.
- b. Drilling.
- c. Completion and workover.
- d. Field production.
- e. Gas plant operations.
- f. Transportation.
- g. Offshore operations.

See Appendix C for a summary of E&P waste sources.

3.2 EXPLORATION

Exploration operations identify locations that contain potential oil and gas deposits. These operations may begin with remote sensing and aerial geomagnetic surveys to identify underground geologic structures where oil and gas may have accumulated. Seismic surveys and related geologic field work are conducted on potential locations.

3.2.1 Seismic Surveys

Prior to drilling an exploratory well, seismic surveys and related geologic field work are the primary exploration activities that generate appreciable amounts of waste. Three basic field work activities contribute to waste generation:

- a. Access to the area of interest.
- b. Construction of seismic lines.
- c. Construction and maintenance of a base camp or campsites.

The environmental impact of each of these efforts should be considered.

3.2.1.1 Accessing Areas of Potential Deposits

Gaining access to an area of potential oil and gas deposits often requires construction of roads or footpaths into remote areas. Construction may involve clearing trees and brush and

temporary displacement of topsoil.

Good management processes include the following:

- Using cleared foliage in soil conservation and control.
- Retaining and replacing topsoil.
- Encouraging revegetation by native flora.

3.2.1.2 Seismic Line Construction

Seismic lines are constructed by clearing a 3- to 6-foot-wide footpath. The root stock and topsoil should be left in place. Shallow holes are typically drilled along the seismic line and explosives are placed in them to be detonated. Any unused shot holes and/or craters caused by explosions should be backfilled to reduce the chance of subsequent erosion. An alternative is to use vehicle-mounted, nonexplosive energy sources.

Wastes generated during this operation include explosives residue, used oil and filters, line stakes or markers, and domestic waste. In general, the volume and toxicity of these wastes are minimal; however, steps should be taken to assure that all nonrecyclable material is either (a) incinerated or buried onsite when allowed by applicable regulations; (b) collected and carried out by the seismic crew once operations cease; or (c) otherwise appropriately managed.

3.2.1.3 Base Camp

Seismic exploration and geologic field work may require a large workforce. In remote areas, a base camp to accommodate personnel and equipment is sometimes necessary. Base camp operations may generate many different wastes.

Base camps are typically self-contained. They will usually consist of personnel accommodations, dining facilities, vehicle/aircraft fueling facilities, and maintenance/parking areas for vehicles and helicopters. Wastes generated include sewage effluent, domestic refuse, used oil and filters, empty petroleum hydrocarbon storage containers, and building material wastes. Disposal of these wastes can be a common problem for base camps in areas where water treatment and waste disposal facilities do not exist. In such cases, provisions must be made for proper treatment or disposal. Specific steps to treatment and disposal include the following:

- All food wastes and other putrefiable material should be collected and properly disposed.
- Solid and hydrocarbon wastes should be evaluated for recycling whenever possible.
- Residue from burned or incinerated wastes should be buried or transported offsite.
- A system for the collection of sewage and water effluents should be constructed and designed to flow through a soak-away system of permeable, earth-covered beds in such a way as to not impact potable water supplies.
- Wastes requiring special handling such as used oil and filters should be kept segregated and disposed in a manner

that prevents surface water or groundwater contamination.

- All material, equipment, and man-made structures (such as buildings, bridges, helipads, and so forth) should be dismantled and removed from the area when work is completed, unless otherwise agreed upon by the landowner and the operators.

The disposal of solid and liquid wastes is controlled by regulation. Landowner consent and/or permits from appropriate authorities may be required before waste disposal methods such as incineration or construction of effluent field can be utilized.

3.2.2 Waste Summary

A list of the major waste categories that may be generated during exploration operations is shown below. See Appendix C for a more complete listing of wastes generated by E&P.

Exploration Operations Wastes

Absorbent material	Sanitary wastewater
Antifreeze	Scrap metal
Batteries	Soil, contaminated
Domestic refuse	Solvents, petroleum naphtha
Domestic wastewater	Stormwater
Filters	Tires
First-aid waste	Unused materials, discarded
Hydraulic fluid	Used oil
Incineration ash	Vegetation
Mud/cuttings from shot holes	Washdown water (rigwash)
Paint related materials	Water, noncontact (for example, cooling or fire water)
Rags, oily	Wood

3.3 DRILLING

Drilling operations are conducted to locate the oil and gas (that is, exploratory drilling), to delineate a discovered reserve or to develop a reservoir for production. The drilling operation has two key components, the drilling rig and the circulation system, which are discussed below.

3.3.1 Drilling Rig

3.3.1.1 Introduction

The drilling rig provides the power and equipment (including safety equipment and systems such as blowout preventers) necessary to drill the wellbore. Its key systems and their uses areas follows:

3.3.1.2 Hoisting System

The hoisting system lifts drill pipe in and out of the well and controls weight on the drill bit as it penetrates rock and



sand formations. It also handles drill pipe when it is out of the wellbore and is used to run casing into the wellbore.

3.3.1.3 Rotating System

The rotating system turns the drill bit so that it can penetrate underground rock and sand formations.

3.3.1.4 Casing

Casing serves the following functions:

- It protects the integrity of the wellbore during drilling.
- It provides a conduit for fluid movement both up and down the wellbore.
- It keeps drilling fluids from leaving the wellbore and seeping into the formation.
- It allows fluids to flow to the surface for processing after well completion.
- It provides protection for underground sources of drinking water.

Wastes generated by the drilling rig result primarily from the operation and maintenance of rig equipment. These wastes include washwater (rigwash), used lubricating oils and filters, solvents, hydraulic fluids, gaskets, used drill bits and pipe, discarded thread protectors, cut drill line, empty grease and pipe dope containers, absorbent materials (such as clay and pads), worn brake pads, and similar materials.

Rigwash, or water used to wash down the rig floor, may contain minor amounts of the detergents that are used to clean the rig and provide a safe work area. The system used to collect rigwash may also collect rainwater.

3.3.2 Circulating System

3.3.2.1 Introduction

The circulating system is the lifeblood of the drilling operation. In this phase, the drilling fluid (that is, mud) is formulated and maintained; circulated downhole to cool the drill bit and flush drilled cuttings from the bottom of the wellbore; used to transport cuttings to the surface where they are mechanically removed from the mud system; and then returned to tanks where the process starts again.

3.3.2.2 Drilling Mud

The drilling mud, mostly water-based clays and inert weighting materials, is formulated using various additives, depending on expected well conditions. Additives help cool the drill bit, lubricate the drill string, and remove the drilled cuttings from the wellbore; they also add the necessary weight to prevent formation fluids from entering the wellbore and support and prevent damage to the underground formations being drilled. In certain geographic regions, spe-

cial drilling fluids such as oil- or saltwater-based muds are used when drilling deep, high-temperature, high-pressure, water-sensitive reservoirs, or high-angle wells.

Wastes generated during drilling mud formulation typically include empty additive containers (such as bags and pails) and unused or contaminated additives.

After formulation, drilling mud is stored in tanks before it is pumped down the drill string. As mud exits the drill bit nozzles, it cools the bit and flushes away any drilled cuttings and solids at the wellbore bottom. The mud then carries these drilled solids to the surface where they are removed using cleaners (such as hydrocyclones or desilters, centrifuges, and shale shakers). These wastes are typically collected in a reserve pit adjacent to the drilling rig.

Wastes generated during drilling operations may include the following:

- Drilling fluids (muds) and solids.
- Cement returns.
- Saltwater.
- Oil.
- Formation cuttings (such as shale, lime, salt, and dolomite).

The waste volumes generated will vary greatly, depending on the well's diameter, depth, type of mud system, and other operating factors.

3.3.2.3 Reserve Pits

Unlined or lined reserve pits store supplies of water, waste drilling fluids, formation cuttings, rigwash, and stormwater runoff from the drilling location. Unlined pits are normally used for freshwater mud systems; lined pits are normally used for oil- or saltwater-based mud systems, or in areas of shallow groundwater, or in those adjacent to fresh surface waters.

Liners may not be necessary for some oil- or saltwater-based mud systems, such as where soil and hydrogeological conditions preclude any adverse impact, or soil, waste mud, and cuttings may be managed to ensure protection of soil and groundwater (for example, treated to fix or solidify contaminants). Conversely, liners may be required in areas that are hydrogeologically or otherwise sensitive. In specific cases, closed-loop drilling mud systems may be required to protect environmentally sensitive areas. These systems do not require reserve pits.

Regulations apply as follows:

- State regulations usually require pit construction to comply with specified land use standards.
- State regulations normally restrict reserve pit usage to the drilling operation and require that pits be closed shortly after cessation of drilling operations (normally within 6-12 months).
- Certain reserve pits may remain open for extended periods because multiple wells may be drilled from a single well pad. Special regulations, including compliance with applicable wa-



ter quality standards for reserve pit contents, may be required in environmentally sensitive areas.

3.3.3 Other Drilling Rig Operations

Support equipment located adjacent to the drilling rig is essential to the drilling operation. Equipment includes fuel tanks, electric power generators, pipe racks, and equipment used to support the maintenance of personnel quarters.

Wastes can include the following:

- Used oil and filters.
- Contaminated fuel and spillage.
- Domestic waste and sanitary sewage.
- Solid waste (including paper sacks, cans, and drums).
- Quarters, garbage, and other materials.

3.3.4 Waste Summary

A list of the major waste categories that may be generated during drilling operations is shown below. See Appendix C for a more complete listing of wastes generated by E&P.

Drilling Operations Waste	
Absorbent material	Polychlorinated biphenyls (PCBs)
Antifreeze	Produced sand
Batteries	Produced water
Blasting sand/material	Radioactive waste, LSA [low specific activity (for example, tracer materials)]
Cement returns	Rags, oily
Completion/W.O./well treatment fluids	Sanitary wastewater
Construction/demolition debris	Scrap metal
Domestic refuse	Soil, contaminated
Domestic wastewater	Solvents
Drill cuttings	Spill cleanup waste, hydrocarbon (for example, crude)
Drilling fluids	Stormwater
Filters	Thread protectors
first-aid waste	Tires
Hydraulic test (BOP) fluids	Unused materials, discarded
Hydraulic fluid	Used oil
Incineration ash	Vegetation
Insulation material	Washdown water (rigwash)
Mud sacks	Water, noncontact (for example, cooling or fire water)
Paint-related materials	Wood
Pallets	

3.4 COMPLETION AND WORKOVER

Once drilling operations are finished, newly drilled wells must be completed before being put into production. There are many methods of completing or preparing a well for

production or injection.

- Generally, the well casing must be perforated to allow fluid flow.
- Downhole equipment may also be installed to facilitate production or injection.
- The producing formation may also be acidized or fractured to enhance production or injection capacity.

Workover rigs are typically used for completion activities; in some cases, drilling rigs are also used. The latter is not normal practice, due to the higher operating cost of a drilling rig as compared to a workover rig. When using a drilling rig, larger quantities of waste may be generated due to the rig's increased size.

In addition, existing production and injection wells require periodic maintenance utilizing workover rigs. Workover operations include installing tubing and packer, acidizing or fracturing stimulations, replacing tubing or pumping equipment, recompleting to new reservoirs, or plugging and abandoning of wellbores. The amount and type of waste generated from completion, well treatment, and workover operations can range from virtually none for chemical treatments and logging operations to large volumes similar to those encountered during drilling operations.

Wastes generated from the workover rig itself include hydraulic fluids, used oils and filters, and other maintenance wastes. Other wastes include spent completion and workover fluids and filters (for example, diatomaceous earth), produced water, produced sand and other solids, spent acids, inhibitors, and solvents.

Spent or used fluids are normally produced through flowlines to production facilities or trucked to operator-owned production facilities for further processing. Workover fluids are also disposed of at commercial facilities when operators are unable to process them in their own production facilities.

A list of the major waste categories that may be generated during completion and workover operations is shown below. See Appendix C for a more complete listing of wastes generated by E&P.

Completions and Workover Operations Waste	
Absorbent material	Pipe/equipment hydrates
Antifreeze	Pipe/equipment scale
Batteries	Pit sludges
Blasting sand/material	Polychlorinated biphenyls (PCBs)
Cement returns	Produced sand
Completion/W.O./well treatment fluids	Produced water
Construction/demolition debris	Radioactive waste, LSA (low specific activity [for example, tracer materials])

Crude oil/condensate, waste	Rags, oily
Domestic refuse	Sanitary wastewater
Domestic wastewater	Scrap metal
Drill cuttings	Soil, contaminated
Drilling fluids	Solvents
Filters	Source sand
First-aid waste	Source water
Hydraulic test (BOP) fluids	Spill cleanup waste, hydrocarbon (for example, crude)
Hydraulic fluid	Stormwater
Incineration ash	Tires
Insulation material	Unused materials, discarded
Naturally occurring radioactive material (NORM)	Used oil
Packing fluids	Vegetation
Paint-related materials	Washdown water (rigwash)
Pallets	Water, noncontact (for example, cooling or fire water)
Paraffin	Wood

3.5 FIELD PRODUCTION

3.5.1 Introduction

After a well is drilled and completed, field facilities collect oil and/or gas from the well and prepare it for sale. Well fluids are often a complex mixture of liquid hydrocarbons, gas, water, and solids. The objective of the production process is to separate constituents of the mixture, remove those that are nonsaleable, and sell the liquid hydrocarbons and gas. Purchasers have contract standards for the oil and gas they will accept. For example, oil purchasers typically limit the amount of basic sediment and water (BS&W) to less than 1 percent. Gas purchasers set similar limits on water, water vapor, hydrogen sulfide (H_2S), carbon dioxide (CO_2), and BTU content.

The field production facility can be grouped into the following areas:

- Wells and gathering systems.
- Oil and produced water treatment systems.
- Dehydration and sweetening.
- Injection operations.
- Oil storage and sales.
- Compression and gas sales.
- Other field production facilities and operations.

The following sections describe each field facility area and the wastes that may be generated from it in the production process.

3.5.2 Wells and Gathering Systems

3.5.2.1 Introduction

Wastes generated at the well site include paraffin, oil and produced water contaminated soils, and used gear box lubrication oil. These wastes are more commonly found at oil wells than at gas wells.

3.5.2.2 Paraffin Removal

Paraffin precipitates within tubing and piping when oil containing paraffin is produced up a wellbore and pressures and temperatures are reduced. Paraffin solvents or dispersants, heating, or mechanical cutting remove it from the tubing and piping. Paraffin solvents, dispersants, and hot treatment fluids are normally handled and treated as part of the crude stream in the field processing facilities. However, paraffin cut with downhole tools is generated at the wellhead.

3.5.2.3 Stuffing Box

Oil and produced water contaminated soils and debris may result from leaks in the stuffing box of a pumping unit or from minor amounts of spillage during well chemical treatment, workover, or servicing operations. The stuffing box on a pumping well is the mechanical seal between the tubing and polished rod. The fluid (for example, crude oil) being pumped acts as the seal lubricant. Because of the continuous wearing action of the polished rod, the stuffing box packing requires periodic adjustment to minimize leakage.

Pumping unit gear box lubricating oil must be replaced occasionally, either because of gear box malfunction or for preventive maintenance.

3.5.2.4 Flow Lines

Flow lines gather produced fluids from wells for transport to field facilities for processing. Periodically, flow lines gathering crude production can plug from a buildup of paraffin and scale. When this occurs, either pipeline pigs are run through the flow lines or hot oil is pumped through them to remove or dissolve the plugging material.

Plugging material that is not dissolved back into the crude oil is recovered at a pig trap at the facility inlet. Recovered paraffin solids can be heated and returned to the production system or hauled to a storage site for future reclaiming or disposal. Scale material is also collected for disposal.

Flow line ruptures or leaks generate crude oil and/or produced water-contaminated soil. Depending on the severity and location of the release, contaminated soils may either be managed in situ or removed for treatment or disposal, either onsite or offsite.

3.5.2.5 Chemical Treating

Treating chemicals such as corrosion inhibitors are sometimes injected into the well or flowline to provide protection. Chemical injection pumps typically dispense chemicals from 55-gallon drums or bulk containers. Leaks from this process may result in chemical-contaminated soils; spills should be minimized via drip pans. Any spill should be managed as described in the preceding paragraph, provided it is also in accordance with applicable state and RCRA regulations (see Section 4).

3.5.3 Oil and Produced Water Treatment Systems

3.5.3.1 Introduction

When produced fluids and solids reach the field facilities, they enter the treatment system. There the gas, crude, water, and solids are separated into individual streams. Each stream is then further treated in preparation for sale or disposal, as applicable.

3.5.3.2 Free-Water Knockout

Typically, the free-water knockout (FWKO) is the first vessel to receive produced fluids. The FWKO separates free water (that is, water not linked to oil in an emulsion) from other produced fluids and solids. Separated produced water then flows into the water treatment system for either disposal or reinjection. Periodically, solids and bottom sludges are removed from the FWKO for reclamation, treatment, or disposal.

3.5.3.3 Separators

Two-phase separators isolate produced liquids from gases as they flow from the wells. Three-phase separators, which have additional float mechanisms, also separate produced water from produced fluids. The gas, oil or condensate, and water are then further processed prior to sale or disposal. The primary waste generated by the separator consists of produced sand, scale, and bottom sludges recovered during cleanout operations.

3.5.3.4 Heater Treaters/Electrostatic Treaters

Heater treaters and/or electrostatic treaters separate emulsified oil and water. Occasionally, emulsions (that is, bad oil) that cannot be treated successfully in a single pass through the treatment system must be placed in a standby oil tank for recycling and further treatment. Produced water separated in the treaters goes to a disposal or injection system. As is the case with the FWKO and other production vessels, these treaters are occasionally drained to remove solids and bottom sludges. Treaters that use hay or excelsior sections to absorb minute amounts of oil must be cleaned out periodically, and the absorption material must be replaced.

3.5.3.5 Desanders

Where produced water carries excessive solids (produced sand), desanders may be utilized to remove these solids. Typically, much of the produced sand is also removed in other treating vessels.

3.5.3.6 Produced Water Treating Equipment

Several types of produced water treating equipment are used to prepare the water for discharge, injection, or other options. Skim tanks, gun barrels, and corrugated plate interceptors (CPIs) rely on gravity and residence time to remove residual free oil and solids from produced water. Recovered oil may be returned to the oil treating system or recycled offsite.

Another type of treatment system utilizes gas flotation. These units are used to remove small concentrations of insoluble oil and grease from produced water. The units agitate the water by injecting a gas, usually natural gas or air, through the liquid stream. This action flocculates the suspended oil, grease, and dirt. The flocculated materials then rise to the surface, where they are skimmed off. This material may also be recovered as oil (for example, returned to the oil treating system).

3.5.3.7 Produced Water Tanks

Produced water tanks may be required to provide storage and additional settling time for sand/solids removal prior to discharge, injection, or other disposal. These tanks must be cleaned occasionally to remove bottoms, including oily sand and solids.

3.5.3.8 Produced Water Discharges to Surface Water

Produced water that is separated from oil and gas may be of sufficient quality to discharge after the above treatment. However, in certain instances, pits or additional tanks are used to separate additional solids and oil from the produced water prior to discharge. Bottoms or sludges are generated if solids are recovered from the settling pit or tank.

3.5.4 Dehydration and Sweetening

Field dehydration and sweetening units perform the same function as that described in greater detail for gas plants in 3.5.2 and 3.5.3. Wastes may include iron sponge, spent glycol, spent amine, spent caustic, and filters and filter media, depending on the type of system operated.

3.5.5 Injection Operations

3.5.5.1 Introduction

Injection operations at field production facilities are used to either dispose of produced water or to enhance recovery of crude oil from the reservoir.



3.5.5.2 Disposal

After initial treatment of produced water, as described above, filtering is frequently used to improve water quality before injection. Filter media must be replaced on a periodic basis; if they are permanent, they must be backwashed.

Replaceable filters include sock, cartridge, or canister units. Permanent filters may use diatomaceous earth or granular media such as sand or coal. Permanent filters are periodically backwashed with fresh or produced water, which sometimes contains a small amount of surfactant.

Backwash should be circulated to a solids treatment and disposal system. There, backwash liquid should be returned to the production facilities for reprocessing.

After filtering, produced water can be injected into the disposal well. An electric motor or gas engine usually drives the injection pump, pressurizing produced water into the injection well. Waste lubricating oil and filters are typically generated at these facilities.

3.5.5.3 Enhanced Recovery

Enhanced recovery is used to maintain pressures in the reservoir and to improve recovery of crude oil from reservoir formations. Several methods of enhanced recovery may be used; these include produced water injection, source water injection, seawater injection, steam flooding, or CO₂ flooding. Although these methods are most common, other methods are also available. The method selected will be dictated by the formation type and method feasibility.

As with injection disposal, water utilized for enhanced recovery must be treated prior to injection. In general, the types of equipment used and the wastes generated are the same as described above.

3.5.5.4 TEOR Steam Generators

In heavy oil operations, steam is sometimes injected into reservoirs to reduce oil viscosity and to enhance fluid production. Traditionally, oilfield operators have generated steam using conventionally fired heaters known as thermally enhanced oil recovery (TEOR) steam generators. The steam these generators make is injected into geological formations containing heavy crude oil; it heats the oil for easier recovery. Injected steam also drives (or pushes) the oil toward producing wells.

TEOR steam generators are fueled by either crude oil, fuel oil, or natural gas. Steam generators fired by crude or fuel oil may have sulfur dioxide air pollution scrubbers associated with them. Steam is also generated and used in some field production facilities and gas plants by burning natural gas.

When burning crude, fly ash impinges on the steam generator convection tubes. To increase thermal efficiency of the generators, fly ash is removed by washing the tubes with water. The resulting effluent is referred to as stack wash water.

Other wastes from steam generators can include fuel oil filters, spent water softening resin, refractory waste, and flue duct ash. Water softening resin is typically used when a central water plant is not available.

3.5.5.5 TEOR Cogeneration Units

Recently, TEOR cogeneration steam generators have replaced some TEOR conventional steam generators. Typically, a TEOR cogeneration steam generator consists of a turbine and its associated heat recovery boilers (steam generators). Cogeneration of electricity and steam can significantly increase the energy efficiency of the process.

TEOR steam generators use soft water (that is, water with low concentrations of dissolved calcium and magnesium). Soft water is used as steam generator feed water to prevent scaling. The water softening process creates a waste fluid identified as regeneration brine. Surplus soft water for disposal (that is, soft water blowdown) is also generated during startup and shutdown of both conventional and cogeneration steam generators.

Waste fluids typically generated at TEOR facilities consist of water softener regeneration brine, surplus soft water (for example, soft water blowdown), excess deionized water, backwash water from the deionization process, scrubber waste (that is, sulfur dioxide liquor), and stack wash.

A typical waste generated at facilities using steam is boiler blowdown water.

3.5.5.6 Air Pollution Control Scrubbers

Air pollution control scrubbers may be required to control sulfur dioxide and particulate matter emissions from exhaust gases of oil-fired TEOR steam generators. The process bubbles exhaust gas through a basic aqueous solution (usually NaOH or Na₂CO₃) which reduces SO₂ to NaHSO₃, Na₂SO₃, and Na₂SO₄. The scrubber liquor waste typically has a neutral pH and low concentration of heavy metals.

3.5.5.7 Deionization

Two other fluids associated only with TEOR cogeneration plants are deionized water and backwash produced from the water purification process. The deionization process involves removing additional dissolved minerals present in water. Deionized water is injected into the turbine combustion chamber to reduce nitrogen oxide emissions. Raw water used in the deionization process is either soft water or fresh water.

Excess deionization water, as well as backwash from this water purification process, may be commingled with excess produced water, regeneration brine, and soft water blowdown prior to disposal.

3.5.6 Oil Storage and Sales

Treated oil that leaves the treatment system goes to oil stock tanks and is ready for sale. Solids and water continue to separate by gravity and accumulate in stock tanks. These tank bottom materials may require periodic removal.

Oil in stock tanks is transported offsite for further processing or refining via pipeline, tank truck, or barge. Wastes generated from onsite transfer operations include lubrication oils, filters, and drips and leaks from pumps and transfer lines. When shipping by tank truck or barge, drainage from transfer hoses can be returned to the system for reprocessing.

3.5.7 Compression and Gas Sales

3.5.7.1 Introduction

Produced gas and fuel scrubbers are used where necessary to separate fluids from gas. After scrubbing, recovered fluids may include condensate, oil, and/or produced waters; these should be returned to the system for reprocessing.

3.5.7.2 Hydrate Prevention

Pressure and temperature decrease as gas is produced from a reservoir. If sufficient water or water vapor exists in the gas stream, hydrates (that is, ice) may form and block flow lines. Methanol is sometimes injected or line heaters are sometimes used to prevent hydrate formation. Methanol is typically used in low concentrations; the concentrations are dictated by field conditions.

The primary waste generated onsite from methanol injection is empty methanol containers. Wastes generated from line heaters include spent thermal fluids (such as glycol, oil, or salt mixtures) used to transfer heat from heat sources to the gas stream.

3.5.7.3 Compressors

Compressors are used to boost the gas pressure to sales line pressure and/or gas lift pressure, inject gas back into the reservoir for pressure maintenance, permit vapor recovery, or allow flow into central facilities. Compressors may be driven by electric motors or by internal combustion or turbine engines.

Wastes generated from compressor operation are identical to those wastes generated by gas plant compressors (see 3.6.2 and 3.6.6). These include engine cooling water containing glycol and used lubrication oil and filters.

3.5.8 Other Field Production Facilities and Operations

Heat exchangers, glycol systems, absorption oil systems, storage tanks, and the like must be cleaned to remove hydrocarbons, salts, scale, and other solids that have built up and reduced field production efficiency.

Internal cleaning of tanks, treating and process vessels, and other equipment is also an operation that can generate wastes.

Wastes generated during cleaning include mixtures of spent cleaning solutions (for example, acids, caustics, solvents, and detergents) and removed solids and/or hydrocarbons.

Other field production facilities or operations that may generate waste include the following:

- Warehousing.
- Equipment maintenance.
- Domestic and sanitary waste handling and treating.
- Construction and demolition.
- Laboratory testing.
- Office, transportation, and maintenance facilities.

3.5.9 Waste Summary

A list of major categories of waste that can be generated during field production operations is shown below. (Note that some of these wastes may be contaminated with naturally occurring radioactive material (NORM) and require special handling.) See Appendix C for a more complete listing of wastes generated by E&P.

Field Production Operations Waste	
Absorbent material	Pipe/equipment scale
Antifreeze	Pit sludges
Batteries	Polychlorinated biphenyls (PCBs)
Blasting sand/material	Produced sand
Boiler blowdown	Produced water
Catalyst	Rags, oily
Cleaning wastes, process equipment	Refractory waste
Completion/W.O./well treatment fluids	Saltbath heater salt
Construction/demolition debris	Sanitary wastewater
Cooling tower blowdown	Scrap metal
Crude oil/condensate, waste	Scrubber liquid, hydrogen sulfide
Deionized water, excess	Soft water, excess
Domestic refuse	Soil, contaminated
Domestic wastewater	Solvents
Filters	Source sand
Flue dust ash (fly ash)	Source water
first-aid waste	Spill cleanup waste, hydrocarbon (for example, crude)
Hydraulic fluid	Storm water
Incineration ash	Sulfur dioxide liquor
Insulation material	Sweetening/dehydration liquids
Lab waste, sample wastes, and residues	Sweetening/dehydration solids
Mercury, metallic liquid	Tank bottoms
Mercury, solids	Tires
Naturally occurring radioactive material (NORM)	Unused materials, discarded



Packing fluids	Used oil
Paint-related materials	Vegetation
Pallets	Washdown water (rigwash)
Paraffin	Water, noncontact (for example, cooling or fire water)
Pigging wastes from gathering lines	Water softener regeneration brine
Pigging wastes from DOT pipelines	Water softening resin, spent
Pipe/equipment hydrates	Wood

3.6 GAS PLANT OPERATIONS

3.6.1 Introduction

Natural gas plants often provide dehydration and compression facilities; sometimes sweetening facilities are provided as well. These plants process natural gas into a marketable condition; they also extract natural gas liquids such as ethane, propane, and butane for separate sale. Natural gas streams entering gas processing plants vary in composition. Methane is the predominant component, but smaller amounts of ethane, propane, butane, pentane, and heavier hydrocarbons are also present. The inlet gas may contain compounds such as carbon dioxide, hydrogen sulfide, mercaptans, other sulfur compounds, water, and certain solid impurities. These can be removed by gas plant treating facilities. Treated gas then enters an extraction facility that removes the heavier natural gas liquids (NGLs) such as ethane, propane, and butane.

Gas plant treating and extraction processes include inlet separation and compression, dehydration, sweetening/sulfur recovery, natural gas liquids recovery, and recompression and plant utilities. Warehousing, product storage, equipment maintenance, domestic and sanitary waste handling and treating, construction and demolition, product shipping, and office facilities are other activities that can occur at a gas plant and generate wastes.

3.6.2 Inlet Separation and Compression

Gas can enter the facility in either an untreated or treated condition. Field production facilities can provide initial treatment; all subsequent treatment, however, is conducted at the gas plant. Produced fluids such as water and liquid hydrocarbons are usually separated at the plant inlet. If necessary, gas will be compressed to a sufficient pressure to allow the plant to operate.

Wastes typically associated with inlet separation include produced water that may contain methanol or other treating chemicals; pigging materials; inlet filter media; fluids from corrosion treatments; and small amounts of solid material (such as, pipe scale, rust, and reservoir formation material).

Wastes generated from plant inlet compressor operations are like wastes generated in field compressor operations.

These include engine cooling water containing glycol and used lubrication oil and filters.

Inlet separators are designed to send produced water and hydrocarbons to process vessels for additional treatment. There, hydrocarbons can be recovered for sale and produced water can be separated for disposal.

Small amounts of pigging materials can also be recovered at the pig receiving traps at the plant inlet.

For safety reasons, inlet separators are equipped with relief valves that vent to emergency containment facilities, that are usually pits. This protects the facility if a fluid slug (for example, produced water) that exceeds separator capacity should reach the plant or if gas pressure exceeds design capacity.

Emergency pits are not disposal facilities; they provide control of emergency releases. Vented fluids should be recovered in accordance with state requirements or operating procedures. The pits should be constructed and operated to prevent groundwater contamination.

3.6.3 Dehydration

All natural gas contains water vapor. Typically, this water content must be reduced to meet sales pipeline specifications. Dehydration is the process of extracting water vapor to make the gas marketable. Processes used at gas plants are like those used at field production facilities where centralized dehydration is unavailable.

Natural gas is dehydrated by contact with either liquid or solid desiccants.

Liquid desiccants such as ethylene glycol, diethylene glycol, or triethylene glycol absorb the water. Heat regeneration evaporates the water, and glycol is recovered for reuse.

In solid desiccant dehydration, natural gas flows through tower vessels filled with alumina, silica-gel, silica-alumina beads, or a molecular sieve to absorb water vapor.

Wastes generated during the dehydration process consist of glycol-based fluids, glycol filters, condensed water, and spent solid desiccants. These fluids and solids may in some circumstances contain trace levels of hydrocarbons and treating chemicals.

3.6.4 Sweetening/Sulfur Recovery

3.6.4.1 Introduction

Some natural gas contains hydrogen sulfide, carbon dioxide, or other impurities that must be removed either for field use or to meet the sales pipeline specifications. The sweetening process may be conducted using units identical in operation to those used at field production facilities where centralized sweetening facilities are not available. It may also be conducted in dedicated sulfur recovery or carbon dioxide (CO₂) removal facilities where high hydrogen sulfide (H₂S) and carbon dioxide concentrations exist.

Sweetening primarily lowers the hydrogen sulfide and carbon dioxide content of natural gas. Hydrogen sulfide is removed from natural gas by contact with amines, sulfinol, iron sponge, iron chelate reduction, caustic solutions, and other sulfur-converting chemicals. Heat regenerates amine and sulfinol for reuse.

In the iron chelate oxidation-reduction process, oxidation (that is, having air as the oxygen source) is used to regenerate the solution. Iron sponge, caustic solutions, and other sulfur-converting chemicals are spent in the process and are not regenerated.

3.6.4.2 Amine Sweetening

Amine treating of natural gas for removal of hydrogen sulfide and carbon dioxide is the process that is probably most widely used in the industry. This process is based on the reaction between aliphatic alkanolamines and acid gases at moderate temperatures. Amines are then regenerated by elevating the temperature to release acid gases.

Wastes generated in amine sweetening include degraded or spent amine; used filter media; and acid gas, which must be flared, incinerated, or sent to a sulfur recovery facility.

3.6.4.3 Sulfinol Sweetening

The sulfinol treating process utilizes an aqueous mixture of an aliphatic alkanolamine (that is, either di-isopropanolamine or methyl diethanolamine) and a physical solvent (that is, Sulfolane). This process involves the chemical reaction of an alkanolamine with hydrogen sulfide and carbon dioxide, and the physical absorption of these acid gases and other sulfur-containing compounds such as carbonyl sulfide (COS), carbon disulfide (CS₂), and mercaptans (RSH) at feed gas pressure and temperature. The acid gases and absorbed gases are released at near atmospheric pressure and somewhat higher temperatures.

Wastes generated in sulfinol sweetening include degraded amine and used filter cartridges or bags. The resulting acid gas waste stream may be flared, incinerated, or sent to a sulfur recovery facility.

3.6.4.4 Iron Chelate Oxidation-Reduction Sweetening

This desulfurization process uses an iron-chelating solution to selectively remove hydrogen sulfide from gas streams through a reduction reaction. When sour gas is contacted with a water solution of chelated iron, the H₂S is converted to elemental sulfur in an iron reduction reaction.

The solution is regenerated by oxidation, normally carried out using air as the oxygen source.

This process uses a nontoxic solution and creates little or no H₂S or SO₂ emissions. The solid waste generated by this sweetening process is a nontoxic wastewater stream.

3.6.4.5 Iron Sponge Sweetening

In the iron sponge treating process, iron oxide reacts with hydrogen sulfide to form iron sulfide. Iron sponge is composed of finely divided iron oxide, coated on a carrier such as wood shavings.

The iron sponge process is generally used for treating gas at pressures less than 50 psig with total hydrogen sulfide content under 100 grains per 100 standard cubic feet.

The waste generated in the iron sponge process is the iron sulfide and wood shavings combination.

3.6.4.6 Caustic Sweetening

Small volumes of hydrogen sulfide may be removed from natural gas and NGLs by contact with a caustic solution, which is reused until spent. Most caustic treaters utilize a 10- to 20-percent by weight sodium hydroxide solution. In it, the caustic consumption is approximately 2.4 pounds per pound of hydrogen sulfide removed, and 1.9 pounds per pound of carbon dioxide removed. Most caustic treaters consist of a simple vessel holding the caustic solution through which gas is allowed to bubble.

The primary waste from caustic treating is spent caustic solution.

3.6.4.7 Other Sulfur-Converting Compounds

Other sulfur-converting compounds such as Sulfa-check are employed in one-step processes to remove low levels of hydrogen sulfide. Here, a direct conversion using a single contact vessel occurs at ambient temperature. Natural gas bubbles through the vessel until the sulfur-converting compound is spent.

The primary waste is a nonhazardous slurry of sulfur and salts.

3.6.4.8 Claus Process Sweetening

The Claus process utilizes amine or sulfinol solutions to remove hydrogen sulfide from sour natural gas.

As part of the regeneration process, hydrogen sulfide is driven out of solution. The hydrogen sulfide is then burned in the presence of oxygen to produce sulfur dioxide. Hydrogen sulfide and sulfur dioxide are then mixed and exposed to a heated catalyst to form elemental sulfur.

The Claus process utilizes pelletized, inert aluminum oxide as a catalyst. The aluminum oxide does not react in the sulfur-making process but merely provides a greater surface area to speed and assist the process.

The primary waste generated is spent catalyst.

3.6.4.9 Molecular Sieve Sweetening

Molecular sieve absorbents are used to remove hydrogen sulfide, mercaptans, and heavier sulfur compounds from

gases and NGLs. They are also used to remove water vapor. Thus, simultaneous sweetening and dehydration may be accomplished in the same unit. Molecular sieve sweetening is a batch-type regenerative operation requiring at least two beds for continuous processing. As one bed is sweetening, the other is regenerating.

The primary waste generated is spent molecular sieve.

3.6.5 Natural Gas Liquids Recovery

NGL recovery is the process by which hydrocarbons heavier than methane, which exist as liquids at moderate pressures, are extracted from natural gas. NGL extraction may use compression and cooling processes, absorption processes, or cryogenic processes. These processes either (a) absorb heavier molecular compounds from the process stream with an absorption oil that is recycled or (b) use temperature and pressure to separate fractions with different boiling points.

Wastes generated include lubrication oils; spent or degraded absorption oil, wastewaters, cooling tower water, and boiler blowdown water.

3.6.6 ReCompression and Plant Utilities

Plant compression and utility systems (including fuel, electrical generators, steam equipment, pumps, and sump systems) are necessary to operate the gas plant and to raise the pressure of the plant outlet gas to match the sales gas pipeline pressure.

Compressors are driven by electric motors, internal combustion, or turbine engines. These engines, compressors, and utility systems generate used lubrication oils; cooling waters; wastewaters; spent solvents such as petroleum naphtha used for cleaning equipment; and oily debris such as rags, sorbents, and filters.

Steam equipment wastes are the same as those described in the field operations in 3.5.5.4.

3.6.7 Other Gas Plant Facilities and Operations

Process cleaning wastes identical to those generated at field production facilities are generated at gas plants. Wastes generated during the cleaning process include mixtures of spent cleaning solutions (such as, acids, caustics, solvents, and detergents) and solids and/or hydrocarbons removed from the system.

Other activities that generate waste are warehousing, product storage, maintenance activities, domestic sanitary waste handling and treating, construction and demolition, product shipping, laboratory testing, and office operations.

3.6.8 Waste Summary

A list of major categories of waste that may be generated at gas plants is shown below. (Note that certain equipment, valves, piping, and so forth may be contaminated with de-

posits of naturally occurring radioactive material (NORM) and should be handled accordingly when removed from service.) See Appendix C for a more complete listing of wastes generated by E&P.

Gas Plant Waste	
Absorbent material	Pit sludges
Antifreeze	Polychlorinated biphenyls (PCBs)
Batteries	Produced sand
Blasting sand/material	Produced water
Boiler blowdown	Rags, oily
Catalyst	Refractory waste
Cleaning wastes, process equipment	Saltbath heater salt
Construction/demolition debris	Sanitary wastewater
Cooling tower blowdown	Scrap metal
Crude oil/condensate, waste	Scrubber liquid, hydrogen sulfide
Deionized water, excess	Soft water, excess
Domestic refuse	Soil, contaminated
Domestic wastewater	Solvents
Filters	Spill cleanup waste, hydrocarbon (for example, crude)
Flue dust ash (fly ash)	Storm water
first-aid waste	Sulfur dioxide liquor
Hydraulic fluid	Sweetening/dehydration liquids
Incineration ash	Sweetening/dehydration solids
Insulation material	Tank bottoms
Lab waste, sample wastes, and residues	Tires
Mercury, metallic liquid	Unused materials, discarded
Mercury, solids	Used oil
Naturally occurring radioactive material (NORM)	Vegetation
Paint-related material	Washdown water (rigwash)
Pallets	Water, noncontact (for example, cooling or fire water)
Pigging wastes from DOT pipelines	Water softener regeneration brine
Pipe/equipment hydrates	Water softening resin, spent
Pipe/equipment scale	Wood

3.7 TRANSPORTATION PIPELINES

When the processing of crude oil and natural gas has been completed at field production facilities or gas plants, the oil and gas are metered and sold. Transportation pipelines transport crude oil or natural gas and associated liquids to the market for sale or refining. These pipelines are usually referred to as transmission lines by the Department of Transportation (DOT).

These facilities and operations are no longer considered uniquely E&P.

3.8 OFFSHORE OPERATIONS

Since many wastes generated at offshore operations are identical to those generated onshore, a separate offshore discussion is not included in this document. From a waste handling and disposal standpoint, offshore operations are unique in that they may have the option to discharge in accordance with their NPDES (National Pollutant Discharge Elimination System) permit. If the waste stream is not permitted for overboard discharge, it must be hauled to shore. Once onshore, the wastes are handled and disposed in much the same manner as those wastes generated at onshore operations.

4 Environmental Legislation and Regulations

4.1 INTRODUCTION

This section summarizes key federal environmental laws and regulations that affect E&P waste management and disposal practices. They impose responsibility and liability for the protection of human health and the environment from harmful waste management practices or discharges.

Users are cautioned, however, that interpretation of regulations varies. Readers should contact appropriate legal counsel for assistance and advice. Information in this document is not all-inclusive and may not be applicable in all situations. State and local requirements vary. Federal, state, and local regulations are constantly evolving and should be compared with the information in this document to ensure consistency. References to specific regulations appear italicized and in brackets. An example of a reference or citation is the definition of solid waste, which is located in 40 *CFR* § 261.2. This refers to Title 40 of the *Code of Federal Regulations*, Part 261, Section 2.

Environmental violations may subject corporations, managers, employees, and shareholders to varying degrees of liability. Liability has now been extended to include personnel who know or should know if a particular action is illegal. Actions cover the gambit from improper recordkeeping to willful violations of appropriate regulations. Individuals may no longer claim ignorance as a defense against prosecution and the subsequent civil and criminal penalties, including imprisonment.

Civil penalties may become quite costly through court and administrative agency involvement. In addition to remediation expenses, fines of \$25,000 per day per violation are no longer uncommon and may also be assessed.

Similarly, the transfer of land may present economic risks from environmental concerns. A careful evaluation of properties should be made to identify these liabilities prior to

transfer. A good record of property condition prior to transfer can be very beneficial in dealing with claims from subsequent owners and government agencies.

4.2 THE RESOURCE CONSERVATION AND RECOVERY ACT (RCRA)

4.2.1 Overview

Enacted in 1976, RCRA required EPA to establish procedures for identifying solid wastes as either hazardous or nonhazardous and promulgate requirements for managing both.

EPA established four different criteria or characteristics to determine whether a waste is hazardous: (a) ignitability, (b) corrosivity, (c) reactivity, and (d) toxicity.

EPA also listed certain specific wastes (including known poisons and carcinogens) as innately hazardous. Thus, hazardous wastes are described as either characteristically hazardous or as listed hazardous wastes.

Hazardous waste management is stringently regulated under RCRA Subtitle C. Nonhazardous waste disposal is regulated under RCRA Subtitle D and depends primarily on state controls. To date, EPA has established criteria aimed at ensuring that nonhazardous waste management facilities operate as sanitary landfills rather than open dumps.

States are required to submit Solid Waste Management Plans for EPA approval and funding. EPA activity and RCRA amendments after 1988 increased the emphasis on Subtitle D wastes and established additional minimum standards that state programs must include for Subtitle D waste management.

4.2.1.1 1980 RCRA Amendment

When RCRA was amended in 1980, the United States Congress recognized the special nature, high volume, and low toxicity of wastes generated by oil and gas exploration and production operations (as well as by mining, geothermal operations, electric utilities, and cement kilns). The U.S. Congress deemed that these wastes required special consideration. Therefore, it exempted oil and gas industry exploration and production wastes from regulation under RCRA hazardous waste provisions (Subtitle C). In addition, the U.S. Congress directed EPA to study such wastes and recommend appropriate regulatory action.

The EPA study was to include analysis of the following:

- a. Sources and volume of waste.
- b. Current disposal practices.
- c. Dangers to human health and the environment, including documented cases.
- d. Alternatives to current disposal methods.
- e. Costs of alternative disposal methods.
- f. Impact of alternative disposal methods on exploration and production.

4.2.1.2 June 30, 1988 EPA Regulatory Determination

EPA conducted the study on E&P wastes and submitted a report to the U.S. Congress on December 28, 1987. Based on that study, the Agency made public its Regulatory Determination on June 30, 1988; it stated:

“The Agency has decided not to promulgate regulations under Subtitle C (for E&P wastes).

Existing State and Federal regulations are generally adequate . . . certain regulatory gaps do exist, however, and enforcement of existing regulations in some States is inadequate.”

EPA listed examples of waste treatment methods and general field practices that, in specific instances, had not been used in an environmentally sound manner. The practices themselves were not at issue; rather, the problem was the lack of state regulations for their oversight. These treatment methods/practices include the following:

- a. Land farming.
- b. Road spreading.
- c. Pit construction.
- d. Surface water discharge.
- e. Central disposal and treatment facility management.
- f. Abandonment of existing and previously abandoned wells.
- g. Arctic operations (in general).
- h. Associated wastes management.

EPA also stated:

“Existing Federal standards under Subtitle D of RCRA. . . do not fully address the specific concerns posed by oil and gas wastes. Nevertheless, EPA has authority under Subtitle D to promulgate more tailored criteria. In addition, the authorities available under the Clean Water Act or Safe Drinking Water Act can be more broadly utilized, and efforts are already underway to fill gaps under these programs.”

In the June 30, 1988, Regulatory Determination, EPA further stated that its plans were as follows:

“The Agency plans a three-pronged approach toward filling gaps in existing State and Federal regulatory programs by:

- a. Improving Federal programs under existing authorities in Subtitle D of RCRA, the Clean Water Act, and Safe Drinking Water Act;
- b. Working with States to encourage changes in their regulations and enforcement to improve some programs; and
- c. Working with the Congress to develop any additional statutory authority that may be required.”

4.2.1.3 1990 IOGCC State Regulatory Guidelines

In 1989, the Interstate Oil Compact Commission (currently IOGCC—Interstate Oil and Gas Compact Commission) formed a Council on Regulatory Needs to assist EPA with its approach to E&P wastes. In 1990, the council produced a study report that represents the IOCC’s initial effort to assist EPA and the states in improving E&P waste management programs. The report outlines goals and criteria for state programs to use in regulating these wastes. In 1994, the IOCCC published an update titled IOGCC Environmental Guidelines for state oil and gas regulatory programs. IOGCC maintains an ongoing effort to peer review state regulatory programs using these guidelines. This effort demonstrates that there is no need to increase federal regulation of E&P wastes.

4.2.2 Definition of Solid Waste (40 Code of Federal Regulations Part 261.2)

In simplest terms, a solid waste is any material that is discarded or intended to be discarded. According to RCRA, solid wastes may be the following:

- a. Solid.
- b. Semi-solid.
- c. Liquid.
- d. Contained gaseous materials.

Specifically excluded from the solid waste definition are certain point source discharges subject to National Pollutant Discharge Elimination System (NPDES) permits under the Clean Water Act. Commercial products—including residues from spill cleanup—are not regulated as wastes unless, and until, they are intended to be discarded. Commercial products may be regulated under other statutes, including:

- a. Federal Insecticide, Fungicide and Rodenticide Act (FIFRA).
- b. Toxic Substances Control Act (TSCA).
- c. Comprehensive Environmental Response Compensation and Liabilities Act (CERCLA).
- d. Superfund Amendments and Reauthorization Act (SARA).

Each of these will be discussed later in this section.

Enhanced recovery describes all efforts to increase ultimate production of oil and gas from a reservoir.

EPA has determined that produced water injected for enhanced recovery is not a waste for purposes of RCRA Subtitle C or D. This is because produced water used in enhanced recovery is beneficially recycled and is an integral part of some crude oil and natural gas production processes. Also, as stated in 4.2, this practice is regulated under the Safe Drinking Water Act’s Underground Injection Control (UIC) Program.

4.2.3 Hazardous Waste Criteria Determination

Under RCRA, a solid waste may be designated as a hazardous waste either by being specifically listed or by exhibiting one of the characteristics identified in the regulations.

Although considered to be a solid waste, as discussed above, wastes that are uniquely E&P have been specifically exempted from being considered hazardous [40 *Code of Federal Regulations* Part 261.4(b)(5)]. See 4.2.6 and 4.2.7 for wastes that have been identified as exempt and 4.2.8 for those identified as nonexempt.

Other wastes are also considered exempt from Subtitle C under other provisions of RCRA (e.g., 40 *Code of Federal Regulations* Part 261.4). These include certain reclaimed materials and point source discharges subject to Section 402 of the Clean Water Act. Thus, a waste considered nonexempt per the E&P exemption may still be considered exempt from regulation as a hazardous waste, provided it meets one of the other exemption categories.

In this document, exempt means an E&P exemption from Subtitle RCRA C regulation only. This is not intended to imply that the waste is exempt from regulation under other statutes/laws.

4.2.3.1 Listed Hazardous Waste (40 *Code of Federal Regulations* Part 261, Subpart D)

EPA has listed numerous types or classes of solid wastes as hazardous because they

- Typically exhibit one or more of the characteristics of hazardous waste (see below).
- Have been shown to meet certain human toxicity criteria.
- Contain any one of the chemical compounds or substances listed as hazardous constituents.

The regulations contain four lists of hazardous wastes:

- Hazardous waste from nonspecific sources (F-listed).
- Hazardous waste from specific sources (K-listed).
- Commercial chemical products considered acutely hazardous when disposed (P-listed).
- Commercial chemical products considered toxic when disposed (U-listed). Chemical containers that are not empty by EPA's definition also are hazardous wastes.

4.2.3.2 Characteristically Hazardous Waste (40 *Code of Federal Regulations* Part 261, Subpart C)

The EPA has developed four tests for use in determining when a solid waste not listed as a hazardous waste, or specifically excluded from regulation as a hazardous waste, must be managed as hazardous. EPA considers any nonexempt waste to be a hazardous waste if it exhibits any one of the characteristics of ignitability, corrosivity, reactivity, or tox-

icity. These characteristics are described in the following sections.

4.2.3.2.1 Ignitability

A solid waste is ignitable if

- It is a liquid and has a flash point less than 60°C (140°F).
- It is not a liquid and is capable of causing fire through friction, absorption of moisture, or spontaneous chemical changes and, when ignited, burns so vigorously and persistently that it creates a hazard.
- It is an ignitable compressed gas.
- It is an oxidizer.

4.2.3.2.2 Corrosivity

A solid waste is a corrosive if

- It is aqueous and has a pH less than or equal to 2 or greater than or equal to 12.5.
- It is a liquid and corrodes steel at a rate greater than 0.25 inches per year.

4.2.3.2.3 Reactivity

A solid waste is reactive if

- It is normally unstable and readily undergoes violent change without detonating.
- It reacts violently with water.
- It forms potentially explosive mixtures with water.
- When mixed with water, it generates toxic gases, vapors, or fumes in a quantity sufficient to present a danger to human health or the environment.
- It is a cyanide- or sulfide-bearing waste which, when exposed to pH concentrations between 2 and 12.5, can generate toxic gases, vapors, or fumes in a quantity sufficient to present a danger to human health or the environment.
- It is capable of detonation or explosive reaction if it is subjected to a strong initiating source or if heated under confinement.
- It is readily capable of detonation or explosive decomposition under normal conditions (standard temperature and pressure).
- It is a forbidden Class A, or Class B explosive as defined by the U. S. Department of Transportation.

4.2.3.2.4 Toxicity

A solid waste is toxic if the extract from a representative sample of the waste contains any of the contaminants specifically listed in 40 *Code of Federal Regulations* Part 261.24 at a concentration equal to or greater than the respective value for each contaminant, thereby failing the Toxicity Characteristic Leaching Procedure Test (TCLP).