Oil and Gas Development (Onshore)

Industry Description and Practices

This document deals with *onshore* oil and gas exploration, drilling, and production operations. Refining operations are covered in a separate document.

Testing, delineation, and production drilling are integral to hydrocarbon reservoir development, which involves the use of drilling rigs, associated equipment such as casing and tubing, large quantities of water, and drilling muds. In the process, oil and gas are moved to the surface through the well bore either through natural means (if the reservoir has enough pressure to push the oil and gas to the surface) or through induced pressure by means of a pump or other mechanism. At the surface, oil, gas, and water are separated. Crude oils with associated gas containing more than 30 milligrams per cubic meter (mg/m^3) of hydrogen sulfide are normally classified as "sour crude." The crude oil may require further processing, including the removal of associated gas. Oil produced at the wells is piped or shipped for use as feedstock in petroleum refineries.

Natural gas is predominantly methane with smaller amounts of ethane, propane, butanes, pentanes, and heavier hydrocarbons. Gas wells produce small quantities of condensate, which may require processing. Separation processes generally use pressure reduction, gravity separation, and emulsion "breaking" techniques. The gas that is produced may be used directly as fuel or as feedstock for the manufacture of petrochemicals. It may also contain small amounts of sulfur compounds such as mercaptans and hydrogen sulfide. Sour gas is sweetened by processes such as amine scrubbing.

Waste Characteristics

The main wastes of environmental concerns associated with onshore oil and gas production are drilling-waste fluids or muds, drilling-waste solids, produced water, and volatile organic compounds. The drilling-waste muds may be freshwater gel, salt water (potassium chloride or sodium chloride), or oil invert–based systems. The oil invert mud systems may contain up to 50%, by volume, of diesel oil.

Drilling wastes may contain drilling muds (bentonite), borehole cuttings, additives (polymers, oxygen scavengers, biocides, and surfactants), lubricants, diesel oil, emulsifying agents, and various other wastes that are specifically related to the drilling activities. Drilling-waste solids, which are made up of the bottom layer of drilling-mud sump materials, may contain drill cuttings, flocculated bentonite, and weighting materials and other additives. Additional wastes from the drilling process include used oils, cementing chemicals, and toxic organic compounds.

Field processing of crude oil generates several waste streams, including contaminated wastewater, tank bottoms that may contain lead, emulsions, and heavy hydrocarbon residues, which may contain polynuclear aromatic hydrocarbons (PAHs). Cooling tower blowdown, boiler water, scrubber liquids, and steam production wastes are also generated, as well as contaminated soil, used oil, and spent solvents.

Wastewaters typically contain suspended solids. To control the growth of microorganisms in sour water, a biocide or hydrogen sulfide scavenger (for example, sodium hypochlorite) is generally used prior to reinjection or disposal of the

Table 1. Wastewater from Crude Processing
(milligrams per liter)

Parameter	Typical values (average)
Oil and grease	7–1,300 (200)
Total organic carbon	30–1,600 (400)
TSS	20–400 (70)
Total dissolved solids (TDS)	30,000–200,000 (100,000)
BOD	120–340
COD	180–580
Phenols	50
Cadmium	0.7
Chromium	2.3
Copper	0.4
Lead	0.2
Mercury	0.1
Nickel	0.4

Table 2. Air Emissions from Oil and Gas Production

Gas production (grams per cubic meter gas produced)	
Sulfur oxides	< 0.1
Nitrogen oxides	10–12
VOCs	0.1–14
Methane	0.2–10
Oil production (grams per cubic meter oil produced)	
Nitrogen oxides	3.7
VOCs	3.3–26

water. Crude pipelines are routinely cleaned by pigging operations, which can lead to spills and to the generation of sludge containing heavy metals. Solid wastes that do not contain toxics are used as backfill material.

Table 1 presents a summary of the characteristics of the overall wastewater stream from crude processing.

Among the main sources of air emissions (see Table 2) are fired equipment, vents, flares (including those from compressor stations), and fugitive emissions. The emissions may contain volatile organic compounds (VOCs), sulfur oxides (SO_x), hydrogen sulfide, and nitrogen oxides (NO_x).

Pollution Prevention and Control

Pollution prevention programs should focus on reducing the impacts of wastewater discharges, oil spills, and soil contamination and on minimizing air emissions. Minimizing the quantity of discharge should be stressed. Process changes might include the following:

- Maximize the use of freshwater gel–based mud systems.
- Eliminate the use of invert (diesel-based) muds. If the use of diesel-based muds is necessary, reuse the muds.
- Recycle drilling mud decant water.
- Use hydrogen sulfide scavengers to prevent degradation of sweet wells by sulfate-reducing bacteria.
- Select less toxic biocides, corrosion inhibitors, and other chemicals.
- Minimize gas flaring. (Note, however, that flaring is preferred to venting.)
- Store crude oil in tanks; tanks larger than 1,590 m^3 should have secondary (double) seals.
- Minimize and control leakage from tanks and pipelines.
- Practice corrosion prevention and monitor above- and below-ground tanks, vessels, pipes, etc.
- Remove hydrogen sulfide and mercaptans from sour gases (releasing greater than 1.8 kg of reduced sulfur compounds per hour) before flaring.
- Use knockout drums on flares to prevent condensate emissions.
- Regenerate spent amines and spent solvents, or send offsite for recovery.
- Use low-NO_x burners in process heaters, especially in those with a design heat input of 4.2×10^{10} joules per hour.
- Provide spill prevention and control measures (bunds, berms, and hard surfacing for storage tanks; pressure relief valves; high-level alarms).
- Recover oil from process wastewaters.
- Segregate stormwater from process water.
- Implement leak detection and repair programs.
- Practice good housekeeping and ensure that appropriate operating and maintenance programs are in place.

A reclamation and closure plan for the site is required. This plan should be developed early in the project and should address the removal and disposal of production facilities in an environmentally sensitive manner, the restoration of the site, and provisions for any ongoing maintenance issues. Where possible, progressive restoration should be implemented.

Target Pollution Loads

Implementation of cleaner production processes and pollution prevention measures can yield both economic and environmental benefits. In drilling operations, the use of fresh water should be minimized by maximizing the use of drilling mud pond decant water. Eliminate sour gas emissions by sweetening and reuse.

Treatment Technologies

Typically, air emissions of toxic organics are minimized by routing such vapors to recovery systems, flares, or boilers. Tail gases are scrubbed to remove sulfur compounds.

The decant from the drilling mud disposal sump is treated by coagulation and settling before discharge. Alternatively, the sump fluids may be injected downhole into an approved disposal formation.

The drained and settled drilling-mud solids are disposed of on land by capping; by mixing, burying, and covering; by trenching; or by encapsulating. Other options include land spreading, land filling, incineration (for destruction of toxic organics), or in situ solidification / fixation.

Effluents from the crude process may be treated using coagulation, de-emulsification, settling, and filtration. Stormwater is settled and if necessary, treated (by coagulation, flocculation, and sedimentation) before discharge.

Emissions Guidelines

Emissions levels for the design and operation of each project must be established through the environmental assessment (EA) process on the basis of country legislation and the *Pollution Prevention and Abatement Handbook*, as applied to local conditions. The emissions levels selected must be justified in the EA and acceptable to the World Bank Group.

The guidelines given below present emissions levels normally acceptable to the World Bank Group in making decisions regarding provision of World Bank Group assistance. Any deviations from these levels must be described in the World Bank Group project documentation. The emissions levels given here can be consistently achieved by well-designed, well-operated, and well-maintained pollution control systems.

The guidelines are expressed as concentrations to facilitate monitoring. Dilution of air emissions or effluents to achieve these guidelines is unacceptable.

All of the maximum levels should be achieved for at least 95% of the time that the plant or unit is operating, to be calculated as a proportion of annual operating hours.

Air Emissions

The emissions levels presented in Table 3 should be achieved.

Liquid Effluents

The effluent levels presented in Table 4 should be achieved.

Ambient Noise

Noise abatement measures should achieve either the levels given below or a maximum increase in background levels of 3 decibels (measured on the A scale) [dB(A)]. Measurements are to be taken at noise receptors located outside the project property boundary.

Table 3. Emissions from Onshore Oil and Gas Production
(milligrams per normal cubic meter, unless otherwise specified)

Parameter	*Maximum value*
VOCs, including benzene	20
Hydrogen sulfide	30
Sulfur oxides (for oil production)	1,000
Nitrogen oxides	
Gas fired	320 (or 86 ng/J)
Oil fired	460 (or 130 ng/J)
Odor	Not offensive at the receptor end[a]

Note: ng/J, nanograms per joule.
a. Hydrogen sulfide at the property boundary should be less than 5 mg/m^3.

Table 4. Liquid Effluents from Onshore Oil and Gas Production
(milligrams per liter, except for pH and temperature)

Parameter	*Maximum value*
pH	6-9
BOD	50
TSS	50
Oil and grease[a]	20
Phenol	1
Sulfide	1
Total toxic metals[b]	5
Temperature increase	< 3°C[c]

Note: Effluent requirements are for direct discharge to surface waters.
a. Up to 40 mg/l is acceptable for facilities producing less than 10,000 tons per day.
b. Toxic metals Include antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, vanadium, and zinc.
c. The effluent should result in a temperature increase of no more than 3° C at the edge of the zone where initial mixing and dilution take place. Where the zone is not defined, use 100 meters from the point of discharge.

	Maximum allowable log equivalent (hourly measurements), in dB(A)	
Receptor	*Day (07:00–22:00)*	*Night (22:00–07:00)*
Residential, institutional, educational	55	45
Industrial, commercial	70	70

Monitoring and Reporting

Frequent sampling may be required during start-up and upset conditions. Once a record of consistent performance has been established, sampling for the parameters listed in this document should be as described below.

Air emissions of the parameters should be assessed annually. Liquid effluents from production operations should be analyzed for the parameters on a daily basis, except for metals, which can be monitored monthly or when there are significant process changes.

Monitoring data should be analyzed and reviewed at regular intervals and compared with the operating standards so that any necessary corrective actions can be taken. Records of monitoring results should be kept in an acceptable format. The results should be reported to the responsible authorities and relevant parties, as required.

Key Issues

The key production and control practices that will lead to compliance with emissions requirements can be summarized as follows:

- Maximize the use of freshwater gel–based mud systems.
- Dispose of drilling muds in a manner that minimizes the impact on the environment. Reuse invert (diesel-based) muds.
- Reuse drilling-mud pond decant water.
- Encourage the reuse of produced water for steam generation when steam is used to stimulate reservoir production.
- Minimize gas flaring.
- Scrub sour gases.

Sources

Alberta Land Conservation and Reclamation Council. 1990. *Literature Review on the Disposal of Drilling Waste Solids.* Alberta Land Conservation and Reclamation Research Technical Advisory Committee Report 90-9. Edmonton.

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United Kingdom, Her Majesty's Inspectorate of Pollution. 1992. "Chief Inspector's Guidance to Inspectors, Environment Protection Act 1990. Process Guidance Note IPR 1/16: Petroleum Processes Onshore Oil Production." Her Majesty's Stationery Office, London.