Multilateral Investment Guarantee Agency

Environmental Guidelines for

Petroleum Refining

Industry Description and Practices

The petroleum industry is organized into four broad sectors: exploration and production of crude oil and natural gas; transportation; refining; and marketing and distribution. This guideline only addresses petroleum refining.

Crude oil is fractionated into liquefied petroleum gas, naphtha (used to produce gasoline by blending with octane boosters), kerosene/aviation turbine fuel, diesel oil, and residual fuel oil. Catalytic cracking and reforming, thermal cracking, and other secondary processes are used to change the chemical composition of straight run fractions into salable products such as fractions or cuts for gasoline or diesel fuel blending. Finishing processes are used to achieve the desired product specifications. Certain refineries also produce feedstocks for the manufacture of lube oils and bitumens. Some refineries also manufacture coke.

Waste Characteristics

Boilers, process heaters, and other process equipment are responsible for the emission of particulates, carbon monoxide, nitrogen oxides (NO_x), sulfur oxides (SO_x), and carbon dioxide.

Sulfur recovery units, combustion units and flares release SO_x. Catalytic cracking regenerators release particulates, NO_x, and SO_x. Catalyst changeovers and cokers release particulates. Volatile organic compounds (VOCs) such as benzene, toluene, and xylene are released from storage, product loading and handling facilities, oil/water separation systems, and as fugitive emissions from flanges, valves, seals, and drains. For each ton of crude processed, refineries may emit about:

- 0.8 kg (ranging from less than 0.1 to 3 kg) of particulate matter;
- 1.3 kg of SO_x (ranging 0.2-6 kg and 0.1 kg with Claus sulfur recovery process;
- 0.3 kg of NO_x (ranging 0.06-0.5 kg); and
- 2.5g of BTX (benzene, toluene, xylene) (ranging from 0. 75 to 6) and 1g with Claus sulfur recovery process.

Of this, about 0.14g of benzene, 0.55 g of toluene, and 1.8 g of xylene may be released per ton of crude processed.

VOC emissions depend upon the production techniques, emission control techniques, equipment maintenance, and climate conditions and may be 1 kg per ton (with a range of 0.5 to 6 kg/t) of crude processed.

Petroleum refineries use relatively large volumes of water especially for cooling systems. Surface water runoff, and sanitary wastewaters are also generated. The quantity of wastewaters generated and its characteristics depend on the process configuration. As a general guide, approximately 3.5-5 m^3 of wastewater per ton of crude is generated when cooling water are recycled. Refineries generate polluted wastewaters, containing BOD_5 and COD levels of approximately 150-250 mg/L and 300-600 mg/L, phenol levels 20-200 mg/L; oil levels of 100 to 300 mg/L in desalter water and up to 5,000 mg/L in tank bottoms; benzene levels of 1 to 100 mg/L, benzo(a)pyrene level of less than 1 to 100 mg/L, heavy metals (chrome and lead levels of 0.1-100 and 0.2-10 mg/L respectively), and other pollutants. The refineries also generate solid wastes and sludges (with a range of 3-5 kg per ton of crude processed), 80% of which may be considered hazardous because of the presence of toxic organics and heavy metals.

Accidental discharges of large quantities of pollutants can occur as a result of abnormal operation in a refinery and potentially pose a major local environmental hazard.

Pollution Prevention and Control

Petroleum refineries are complex plants, where the combination and sequence of processes is usually very specific to the characteristics of the raw materials (crude oil) and the products. Specific pollution prevention or source reduction measures can often only be determined by the technical staff. However, there are a number of broad areas where improvements are often possible and site specific waste reduction measures in these areas should be designed into the plant and targeted by management of operating plants. Areas where effort should be concentrated include:

Reduction of Air Emissions

- Minimize losses from storage tanks and product transfer areas by methods such as vapor recovery systems and double seals.
- Minimize sulfur oxide emissions by either desulfurization of fuels (to the extent feasible) or directing the use of high sulfur fuels to units equipped with sulfur oxide emission controls.
- Recover sulfur from tail gases in high efficiency sulfur recovery units.
- Recover nonsilica based (i.e., metallic) catalysts and reduce particulate emissions.
- Use low NO_x burners to reduce NO_x emissions.
- Avoid and limit fugitive emissions by proper process design and maintenance.
- Maintain fuel usage to a minimum.

Elimination/Reduction of Pollutants

- Consider reformate and other octane boosters instead of tetraethyl lead and other organic lead compounds for octane boosting.
- Use non-chrome based inhibitors in cooling water, where inhibitors are needed.
- Use long life catalysts and regenerate to extend the catalysts' life cycle.

Recycling/Reuse

- Recycle cooling water and where cost-effective, treated wastewater.
- Maximize recovery of oil from oily wastewaters and sludges. Minimize losses of oil to the effluent system.
- Recover and reuse phenols, caustics and solvents from their spent solutions.
- Return oily sludges to coking units or crude distillation units.

Operating Procedures

- Segregate oily wastewaters from stormwater systems.
- Reduce oil losses during tank drainage used to remove water before product dispatch.
- Optimize tank and equipment cleaning frequency to avoid accumulating residue at the bottom of the tanks.
- Prevent solids and oily wastes from entering the drainage system.
- Institute dry sweeping instead of washdown to reduce wastewater volumes.
- Establish and maintain an Emergency Preparedness and Response Plan and carry out frequent training.
- Practice corrosion monitoring, prevention and control in underground piping and tank bottoms.
- Establish leak detection and repair program.

Target Pollution Loads

Implementation of pollution prevention measures can provide both economic and environmental benefits. However, a balance on energy usage and environmental impacts may have to be arrived at. The following production-related targets can be achieved by measures such as those detailed in the previous section. The values relate to the production processes before the addition of pollution control measures.

New refineries should be designed to maximize energy conservation, and reduce hydrocarbon losses. A good practice target for simple refineries (i.e. refineries with distillation, catalytic reforming, hydrotreating, and off-site facilities) is that the total quantity of oil consumed as fuel and lost in production operations should not exceed 3.5% of the throughput. For refineries with secondary conversion units (i.e. hydrocrackers, lube oil units), the target should be 5 to 6% (and in some cases, up to 10%) of the throughput. Fugitive VOC emissions from the process units can be reduced to 0.05% of the throughput with total VOC emissions of less than 1 kg/ton of crude (or 0.1% of throughput). Methods of estimating these figures include emissions monitoring, mass balance, and inventories of emissions sources. Design assumptions should be recorded to allow for subsequent computation and reduction of losses.

Vapor recovery systems to control losses of VOCs from storage tanks and loading areas should achieve 90 to 100% recovery.

Plant operators should aim at using fuel with less than 0.5% sulfur (or an emission level corresponding to 0.5% sulfur in fuel). High sulfur fuels should be directed to units equipped with sulfur oxide controls. Fuel blending is another option. A sulfur recovery system with at least 97 percent but preferably over 99% sulfur recovery should be used when the hydrogen sulfide concentration in tail gases exceeds 230 mg/Nm^3. The total release of sulfur dioxide should be below 0.5 kg per ton for a hydroskimming refinery and below 1 kg per ton for a conversion refinery.

A wastewater generation rate 0.4 m^3/t of crude processed is achievable with good design and operation and new refineries should achieve this target as a minimum.

The generation rate of solid wastes and sludges should be less than 0.5% of the crude processed and should aim for 0.3%.

Treatment Technologies

Air Emissions

Control of air emissions normally includes the capturing and recycling or combustion of emissions from vents, product transfer points, storage tanks, and other handling equipment. Boilers, heaters, other combustion devices, cokers, and catalytic units may require particulate matter controls. Carbon monoxide boiler is normally a standard practice in fluidized catalytic cracking units. Catalytic cracking units should be provided with particulate removal devices. Steam injection in flaring stacks can reduce particulate matter emissions.

Liquid Effluents

Refinery wastewaters often require a combination of treatment methods to remove oil and other contaminants before discharge. Separation of different streams (such as stormwater, cooling water, process water, sanitary, sewage, etc.) is essential to minimize treatment requirements. A typical system may include sour water stripper, gravity oil/water separation, dissolved air flotation, biological treatment and clarification. A final polishing step using filtration, activated carbon, or chemical treatment may also be required. Achievable pollutant loads include: BOD_5 of 6g, COD of 50g, suspended solids of 10g, and oil and grease of 2g, all per ton of crude processed.

Solid and Hazardous Wastes

Sludge treatment is usually performed using land application (bioremediation), or solvent extraction followed by combustion of the residue or used in asphalt, where feasible. In some cases, the residue may require stabilization prior to disposal to reduce the leachability of toxic metals.

Oil is recovered from slops using separation techniques such as gravity separators and centrifuges.

Emission Guidelines

Emission levels for the design and operation of each project must be established through the Environmental Assessment (EA) process, based on country legislation and the *Pollution Prevention and Abatement Handbook* as applied to local conditions. The emission levels selected must be justified in the EA and acceptable to MIGA.

The following guidelines present emission levels normally acceptable to the World Bank Group in making decisions regarding provision of World Bank Group assistance, including MIGA guarantees; any deviations from these levels must be described in the project documentation.

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 following emissions levels should be achieved:

Emissions from the Petroleum Industry

Parameter	*Maximum value milligrams per normal cubic meter (mg/Nm^3)*
Particulate matter (PM)	50
Nitrogen oxide (NO_x)*	460
Sulfur oxide (SO_x)	150 for sulfur recovery units and 500 for other units.
Nickel and Vanadium (combined)	2
Hydrogen sulfide	15

*excluding NO_X emissions from catalytic units.

Liquid Effluents

The following effluent levels should be achieved.

Effluents from Petroleum Industry

Parameter	*Maximum value milligrams per liter (mg/L)*
pH	6 - 9
BOD_5	30
COD	150
Total suspended solids	30
Oil and grease	10
Chromium (hexavalent)	0.1
Chromium (total)[2]	0.5
Lead	0.1
Phenol	0.5
Benzene	0.05
Benzo(a)pyrene	0.05
Sulfide	1
Nitrogen(total)	10
Temperature increase	less than or equal to 3°C[2]

[1] The maximum effluent concentration of nitrogen (total) may be up to 40 mg/L in processes that include hydrogenation.

[2] The effluent should result in a temperature increase of no more than 3 degrees Celsius at the edge of the zone where initial mixing and dilution takes place. Where the zone is not defined, use 100 meters from the point of discharge provided there are no sensitive ecosystems within this range.

Note: Effluent requirements are for direct discharge to surface waters. Discharge to an **offsite wastewater treatment plant** should meet applicable pretreatment requirements.

Solid Wastes and Sludges

Wherever possible, generation of sludges should be minimized to 0.3 kg/ton of crude processed with a maximum of 0.5 kg/ton of crude processed. Sludges must be treated and stabilized to reduce concentrations of toxics (such as benzene and lead) in leachate to acceptable levels (such as levels below 0.05 mg/kg).

Ambient Noise

Noise abatement measures should achieve either the following levels or a maximum increase in background levels of 3 dB(A). Measurements are to be taken at noise receptors located outside the project property boundary.

Ambient Noise

Receptor	Maximum dB(A)
Residential; institutional; educational	L_{dn} 55
Industrial; commercial	L_{eq} (24) 70

The emission requirements given here can be consistently achieved by well-designed, well-operated and well-maintained pollution control systems.

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 above should be as detailed below.

Air emissions from stacks should be monitored once every shift if not continuously for opacity (a maximum level of 10%). Air emissions of hydrogen sulfide from a sulfur recovery unit should be monitored on a continuous basis. Annual emissions monitoring of combustion sources should be carried out for SO_x (sulfur content of the fuel with monitored on a supply tank basis) and NO_x.

Liquid effluents should be monitored daily for all the parameters cited above except for metals which should be monitored on at least a monthly basis.

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. These should be reported to the responsible authorities and relevant parties, as required, and provided to MIGA if rquested.

Key Issues

The following box summarizes the key production and control practices that will lead to compliance with emissions guidelines:

- Use vapor recovery systems to reduce VOC emissions.
- Install sulfur recovery systems, where feasible.
- Use low NO_x .burners.
- Maintain fuel and losses to 3.5% for simple refineries and below 6% (with 10% as maximum) for refineries with secondary processing.
- Recover and recycle oily wastes.
- Regenerate and reuse spent catalysts and solvents.
- Recycle cooling water and minimize wastewaters.
- Segregate storm water from process wastewater.
- Use non-chrome based inhibitors (use only to the extent needed in cooling water).
- Minimize the generation of sludges.
- Install spill prevention and control measures.

Further Information

The following are suggested as sources of additional information (these sources are provided for guidance and are not intended to be comprehensive):

Bounicore and Davis. 1992. *Air Pollution Engineering Manual*. New York: Van Nostrand Reinhold Publications.

Commission of the European Communities, DG XI A3. 1991. Technical Note on the Best Available Technologies to Reduce Emissions of Pollutants into the Air from the Refining Industry.

Commission of the European Communities, DG XI A3. 1993. Techno-economic study on the reduction measures, based on best available technology, of water discharges and waste generation from refineries.

U.S. Environmental Protection Agency (USEPA). 1982. Development Document for Effluent Limitations Guidelines and Standards for the Petroleum Refining Point Source Category.

World Bank, Environment Department. 1996. "Pollution Prevention and Abatement: Petroleum Refining." Technical Background Document.