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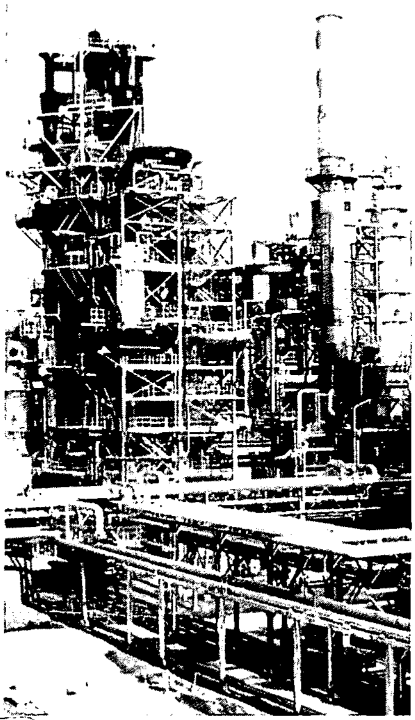

Environmental Status Report for the Canadian Petroleum Refining Industry 1987

Report EPS 1/PN/3
July 1990

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ENVIRONMENTAL STATUS REPORT FOR THE CANADIAN PETROLEUM REFINING INDUSTRY 1987

by

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ABSTRACT

This report provides an overview of the Canadian petroleum refining industry with respect to liquid waste releases. Federal and provincial effluent requirements are presented. An assessment of the state of compliance of the industry with the Federal Petroleum Refinery Effluent Regulations and Guidelines for the year 1987 is also provided. In 1987, Canadian refineries were, on average, in compliance with the monthly amounts more than 94% of the time, stormwater limits 92% of the time, and more than 99% of the time with the daily limits.

RÉSUMÉ

Le présent rapport porte sur l'industrie du raffinage du pétrole au Canada, et plus particulièrement sur ses rejets de résidus liquides. Le cas échéant, les exigences fédérales et provinciales en matière d'effluents sont présentées. Le rapport contient également une évaluation du degré de conformité de l'industrie aux règlements et directives fédéraux sur les effluents des raffineries de pétrole, pour l'année 1987. En 1987, les raffineries canadiennes ont respecté les quantités mensuelles imposées plus de 94 p. 100 du temps, les limites sur les rejets dans les eaux pluviales 92 p. 100 du temps et les limites quotidiennes plus de 99 p. 100 du temps.

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This report was based on a previous version written by Marie Louise Geadah of the Industrial Programs Branch.

GLOSSARY

Activated carbon	Carbon that is specially treated to produce a very large surface area that is used to adsorb undersirable substances.
Actual deposits	The amount of contaminants discharged in refinery effluents.
Adsorption	Attraction exerted by the surface of a solid for a liquid, or a gas when they are in contact.
Aerobic bacteria	Bacteria that require free oxygen to metabolize nutrients.
Air blowing	Refers to the process used to produce asphalt by reacting residual oil with air at moderately elevated temperatures.
Altered refinery	An altered refinery is an existing refinery in which the primary crude oil atmospheric distillation tower was replaced (after October 31, 1973).
Anti-icing additive	A fuel additive used to minimize ice formation.
Antiknock compound	Chemical compounds such as tetraethyllead and aromatic hydrocarbons, that are added to motor and aviation gasolines to improve their performance and to reduce knock in spark-ignition engines.
Anti-oxidants	Chemicals added to products such as gasoline and lubricating oil to inhibit oxidation.
APHA	American Public Health Association
API	American Petroleum Institute
Authorized deposits	The amount of contaminant that is authorized by the federal regulations and guidelines, to be discharged in the effluent of a refinery.
Bioaccumulate	Accumulate in the food chain.
Biodegradation	Process whereby a substance is decomposed by micro-organisms.
Blowdown	Removal of liquid from a refinery vessel (storage or process) through the use of pressure.
BOD	Biochemical Oxygen Demand. The amount of dissolved oxygen required by aerobic microorganisms to biodegrade organic matters contained in wastewater. The BOD test is used to measure the organic content of wastewater and surface water.

BOD_5	Test procedure for measuring BOD for 5 days of 20°C.
Bottom sludge	Heavy material, usually composed of oil, water and impurities, which collects in the bottom of storage tanks or vessels.
BPT	Best Practicable Treatment Technology.
BTEX	Benzene, Toluene, Ethylbenzene and Xylene.
BTX	Benzene, Toluene, Xylene.
Carcinogenic	Cancer-producing agent.
Catalyst	A substance which alters the velocity of a chemical reaction without itself being altered.
CO Boiler	The carbon - monoxide waste-heat boiler is used to recuperate the heat of combustion of carbon monoxide and other combustible (mainly hydrocarbons). The feed is oxidized producing carbon dioxide and water.
COD	Chemical Oxygen Demand. The amount of oxygen equivalent of the organic matter required to complete chemical oxidation in an acidic medium. The COD test is used to measure the organic content of wastewater and natural water.
Cone-roof tank	A type of hydrocarbon-storage tank with a roof in the form of a flat inverted cone to provide vapour space for filling operations.
Cooling tower	A large structure (usually wooden) in which atmospheric air is circulated to cool water by evaporation.
Cyclone	Device for particulate control, whereby particles (larger than 10 μm) are separated from the carrier gas through centrifugal force.
Daily limits	Refers to the limits of One-day amount and of Maximum daily amount in the federal regulations and guidelines.
DEA	Diethanolamine.
Dispersion	Scattering of particles (liquid or solid) under certain forces, that leads to a non-uniform distribution.
Electrostatic precipitator	A device which removes fine particles such as dust, fumes and mists from flue gases. The particles are first exposed to a high-voltage electric field and then attracted to highly charged collecting plates.

Existing refinery	A refinery that started operation prior to November 1, 1973.
Expanded refinery	An existing refinery which has declared a revised reference crude rate that is more than 115% of the initial reference crude rate.
FCCU	Fluid Catalytic Cracking Unit.
FGD	Flue Gas Desulphurization.
Flares	Devices used to burn unwanted gas through a pipe or stack.
Floating-roof tank	An oil storage tank with a flat roof that floats on the surface of the oil reducing evaporation losses to a minimum.
Flue gas	Residual gas with low heating value produced from the combustion of fuel.
Fractionator	A cylindrical refining vessel where liquid feedstocks are separated into various components or fractions (e.g., distillation).
GVRD	Greater Vancouver Regional District.
Heat value	The heat liberated by the combustion of a unit quantity of a fuel.
Landfarm	An area where petroleum processing wastes are applied to the upper soil layers (i.e., landspread) so that soil microorganisms degrade the organic matter in the waste.
Landfill	A location where solid waste is buried in layers of earth in the ground for disposal.
Leachate	A solution resulting from the dissolving of soluble material from soil or solid waste by the action of percolating water or rainfall.
Liquid-liquid extraction	The process where two immiscible liquids are in contact to allow for the soluble material in the carrier liquid to be extracted in the solvent.
LPG	Liquefied Petroleum Gas.
Maximum daily amounts	A limit set in the federal regulations and guidelines for a number of parameters. This limit should not be exceeded on any day of the month in the refinery effluent.
MEA	Monoethanolamine.
Mercaptans	A group of organosulphur compounds having the general formula R-SH where "R" is a hydrocarbon radical such as

	CH_3 and C_2H_5. Mercaptans have strong, repulsive, garlic-like odours and are found in crude oil.
Metabolite	A final or intermediary product of physical and chemical processes that are carried out by an organism. These processes include the degradation of complex organic compounds and the synthesis of complex substances for use by an organism.
Molecular sieve	A synthetic zeolite mineral with pores that is capable of separating molecules on the basis of their size and/or structure. Molecular sieves are used in refineries to remove traces of water from jet fuel and for separating certain mixture of hydrocarbons.
Monthly amounts	A limit set in the federal regulations and guidelines for a number of parameters. This limit represents the amount that should not be exceeded on a daily average basis over each month in the refinery effluent.
Mutagenic	An agent that produces an abrupt change in the genetic material of an organism.
New refinery	A refinery that has not commenced the processing of crude oil prior to November 1, 1973.
NGL	Natural Gas Liquids.
96-hour flow-through bioassay	A test procedure required by the federal guidelines to evaluate the acute lethal toxicity of refinery effluent to fish. The procedure consists of exposing fish to a continually renewed effluent under controlled conditions over a 96-hour period. The percent mortality of fish is observed after the four-day period.
96-hour static bioassay	A test procedure similar to the 96-hour flow-through method but where the effluent is not renewed during the period of test.
Octane	A number indicating the relative antiknock value of a gasoline. The higher the octane number, the greater the antiknock quality.
Once-through cooling water	Water that has been circulated once through heat exchangers in order to remove heat from process streams without coming into contact with the stream.
One-day amounts	A limit set in the federal regulations and guidelines for a number of parameters in refinery effluents. Each refinery is allowed to exceed this limit only once during a month.

Ozonation	Water treatment method used to remove micropollutants (i.e., chemical pollutants present in small concentrations that are difficult to remove) or to disinfect water through the use of ozone as oxidant.
PACE	Petroleum Association for Conservation of the Canadian Environment.
PAH	Polynuclear Aromatic Hydrocarbons.
Photosynthetic action	A process by which organic compounds (mainly carbohydrates) are synthesized by chlorophyll-containing plant cells. The reaction takes place in the presence of light, carbon dioxide and water.
Phytotoxicological Substance	A substance toxic to plants.
Poly gasoline	A product of polymerization of normally gaseous hydrocarbons to form high-octane liquid hydrocarbons boiling in the gasoline range. Also called polymer gasoline.
Priority pollutants	A list of 129 toxic pollutants having known or suspected adverse effects upon human health or the environment. The U.S. EPA established this list and has the mandate to control these pollutants in wastewater discharged to the environment, under the Clean Water Act.
Reference Crude Rate (RCR)	The quantity of crude oil (expressed in 1000 m^3/d) declared by a refinery and that is used to calculate the authorized deposits. The reference crude rate is based on the actual crude oil rate processed by a refinery.
Residual pitch	A black, heavy residue produced in asphalt processing.
Sour water	Water containing impurities, mainly hydrogen sulphide or other sulphur compounds that make it extremely harmful.
Stripping	The removal of the more volatile components from a mixture. Generally, the process consists of passing the hot liquid from a flash drum or tower into a stripping vessel through which open steam or inert gas is passed to remove the more volatile components of the liquid.
TOD	Total Oxygen Demand. Amount of oxygen required to oxidize organic substances and, to a minor extent, inorganic substances in a platinum-catalyst combustion chamber. The TOD test is another method used to measure the organic content of wastewater.

24-hour static bioassy	A test procedure similar to the 96-hour static method but where the percent mortality of fish is observed after a 24-hour period.
U.S. EPA	The United States Environmental Protection Agency
Volatilization	The conversion of a chemical substance from a liquid or solid state to a gaseous state by the application of heat and/or pressure. Also known as vaporization.
Zeolite catalyst	A catalyst that contains any of the various hydrous silicates (e.g., hydrated aluminum and calcium (or sodium) silicates) used in catalytic cracking units.

METRIC CONVERSIONS

1 barrel (bbl)	= 0.158 987 3 cubic metres (m^3)
1 pound (lb)	= 0.453 6 kilogram (kg)
1 lb/1000 bbl	= 2.853 kg/1000 m^3

SUMMARY

This report provides an overview of the Canadian petroleum refining industry and a comprehensive review of its liquid wastes and its pollution control methods. In addition, an assessment of the state of compliance of the industry with the Federal Petroleum Refinery Effluent Regulations and Guidelines for the year 1987 is provided. Federal and provincial effluent waste requirements are identified and discussed.

In 1987, 29 refineries were operating in Canada with a total crude throughput of approximately 248 000 cubic metres per day. Forty-nine percent of the industry was concentrated in Ontario and Quebec. Western & Northern, which is a major production area, had about 25% of the refining capacity.

Petroleum refineries were assessed for compliance with the federal regulations and guidelines for effluent discharge. Of the 29 refineries operating during all or part of 1987, seven were subject to the regulations and the remaining were subject to the guidelines. One refinery was not assessed because it had no discharge during the year, and two (subject to the regulations) used deep-well injection for disposal of all their process effluents and were assessed only for stormwater discharges. Of the remaining 26 refineries, 9 were in compliance with all the limits more than 99% of the time, and seven were in compliance between 95% and 99% of the time. Among the remaining 10 refineries, three had further treatment provided off-site. On a national basis, the refineries were in compliance, on average, with the monthly amounts more than 94% of the time, with the daily limits more than 99% of the time, and with the stormwater limits 92% of the time. In general, the regulations and guidelines limits were exceeded when the wastewater treatment systems were under upset conditions or suffered from mechanical deficiencies. Once the problems had been identified, corrective measures were taken to improve the quality of the effluent. The refinery performance generally improved in 1987 from 1983.

Of the five refineries that were subject to the regulations for process effluent in 1987, four were in compliance 100% of the time, the other one was in compliance 70% of the time. This refinery came on stream in June 1987.

From 1972 to 1987, there was a general downward trend for the net discharges (expressed in kg/d) of all the regulated parameters. Oil and grease was reduced by 44%; total suspended solids by 22%, phenols by 21%; sulphide by 67% and ammonia nitrogen by 40% from the 1983 levels. These reductions were not only caused by the 3% drop in

production, but by the industry's continuous effort to meet and exceed federal and provincial requirements. This was achieved by the upgrading and replacement of existing facilities, and by the installation of efficient treatment systems at new refineries.

On average, 35% of the tests requested to be done by the regulations and guidelines were not reported in 1987. This is primarily because some refineries addressed only the provincial or municipal monitoring and reporting requirements which in some cases are different from the federal requirements.

A majority of the refineries (76%) use a secondary treatment system to treat their effluent or treat their effluent with a primary or intermediate treatment on-site first and then send their effluent to an off-site facility for further treatment. Under good operating conditions, the existing treatment systems can easily meet the limits prescribed by the federal regulations and guidelines. Often levels are reached that are well below the limits. Environment Canada and PACE have commissioned a number of studies in the past few years to characterize refinery wastewaters and assess the effectiveness of existing treatment systems in reducing the concentrations of trace contaminants (10,11,12). The major conclusion drawn from these studies is that a well-operated wastewater treatment system which uses "best practicable treatment technology" (used by most refineries) is very efficient in removing organic priority pollutants from refinery wastewaters, while most metals will be concentrated in the sludges.

1 INTRODUCTION

In November 1973, Environment Canada issued the Petroleum Refinery Effluent Regulations and Guidelines (1) under the Federal Fisheries Act (2). The regulations and guidelines do not apply to facilities associated with the production of synthetic petroleum from coal or bituminous sands. Status reports on the industry's compliance with the regulations and guidelines have been published by Environment Canada for 1975, 1977, 1980, 1983 and 1984. Refineries are identified by name and location, consistent with the department's policy on "information availability" which was announced in 1982 to comply with the Access to Information Act (3).

The compliance assessment is based on reports prepared by the regional offices of Environment Canada in cooperation with industry and the respective provincial environmental agencies. Environment Canada and the provincial agencies periodically audit refinery effluents through field surveys. A discussion of federal and provincial regulatory requirements and current pollution abatement technologies is also presented.

For the purpose of this report, Canada was divided into five regions: the Atlantic region (including Newfoundland, New Brunswick, Nova Scotia and Prince Edward Island); the Ontario region (just the province of Ontario); the Quebec region (just the province of Quebec); the Western & Northern region (including Manitoba, Saskatchewan, Alberta and the Northwest Territories); and the Pacific & Yukon region (including British Columbia and the Yukon Territory). The assessment of the industry's compliance with the regulations and guidelines was made on a national, regional, and individual refinery basis.

2 DESCRIPTION OF THE PETROLEUM REFINING INDUSTRY

In 1987, there were 29 petroleum refineries operating in Canada with a total crude throughput of approximately 248 000 m^3/d. Refineries in Ontario and Quebec were processing 49% of the total crude, while the large production area of the Western & Northern region (mostly Alberta) was processing 25%. One new refinery began operating in June 1987.

The primary function of a petroleum refinery is to separate crude oil and convert it into products such as: gasoline, diesel fuel oil, heavy and light fuel oils, petrochemical feedstock, aviation fuels, asphalt, liquefied petroleum gas (LPG), lubricants, kerosene, stove oil, and other products. Based on 1987 data, gasoline accounted for 38% (by volume) of the total production, followed by diesel fuel oil (18%) and light and heavy fuel oils (9% and 8% respectively).

Crude oil is the principal raw material for a petroleum refinery. It may be of natural origin (from underground geologic formations) or synthetic (recovered from tar sands). Crude oil is a mixture of many hydrocarbons and, depending on its source, varies considerably in composition and physical properties. Its elementary composition usually falls within the following ranges: 84 to 87% carbon (by weight), 11 to 14% hydrogen, 0 to 3% sulphur, 0 to 1% nitrogen, 0 to 2% oxygen, 0 to 1% water and 0 to 0.1% mineral salts. In addition, crude oil may contain trace amounts of heavy metals such as iron, arsenic, chromium and vanadium. Crude oils are broadly classified by hydrocarbon composition as: paraffinic (not prevalent in Canada), naphthenic, asphaltic, mixed (contains paraffin and asphaltic material), and aromatic base (prevalent in the Middle East).

2.1 General

There are four major steps taken to convert crude oil into various products - **separation, conversion, treating** and **blending.** Crude oil is first separated into selected fractions mainly by distillation and to a lesser extent by solvent extraction and crystallization. Conversion processes are used to change the size and shape of the hydrocarbon molecules so that they have greater monetary value. These processes include: catalytic cracking (to break molecules into smaller ones); catalytic reforming and isomerization (to rearrange molecules); and alkylation/polymerization (to join molecules together). Impurities such as sulphur, nitrogen, and oxygen compounds that end up in intermediate products are removed or modified by treatment processes such as desulphurization, denitrification, or treatment with chemical (caustic or acid). As a final step, the refined products are usually blended and some additives are added to improve the quality so that they meet finished product specifications. A simplified flow diagram of the various refinery processes and products is shown in Figure 1.

2.2 Industry Processes

2.2.1 Separation.

Atmospheric Distillation. In this process, the crude oil is first preheated, and mixed with water in a desalter. The water is then separated from the crude, taking with it the salts entrained in the oil from the geological formation. The desalted crude is then reheated and fed to the distillation column at slightly above atmospheric pressure. The crude is then separated, by distillation and steam stripping, into fractions of specific boiling temperature range. The various fractions are continuously drawn off and diverted for further processing or used as finished products. The lighter products are withdrawn from the top of the column whereas lower points on the tower draw off progressively heavier fractions. The tower bottoms, which contain the heaviest petroleum fraction, are transferred to a vacuum distillation tower for further separation.

Vacuum Distillation. In this process, the residue from the atmospheric distillation tower is separated under vacuum into a heavy residual pitch, one or more heavy gas oil streams, and residuals.

2.2.2 Conversion

Cracking Processes. Typical cracking processes include catalytic cracking, hydrocracking, and visbreaking or coking (both thermal cracking processes).

a) Catalytic cracking is a key process to increasing the quality and quantity of gasoline fractions. The most commonly used is the fluid bed type. The process uses a finely powdered zeolite catalyst that is kept in suspension in the reactor by the incoming oil feed from the bottom of the reactor. Upon contact with the hot catalyst the oil vaporizes and is cracked into smaller molecules. Vapours from the reactor are separated from the entrained catalyst and fed into the fractionator, where the desired products are removed and heavier fractions are returned to the reactor. The catalyst is deactivated by thermal degradation and through contact with heavy metals in the feed, necessitating regeneration or replacement.

b) Hydrocracking is basically a catalytic cracking and a hydrogenation process. In this process polycyclic compounds are broken to produce single ring and paraffin-type hydrocarbons. In addition, sulphur and nitrogen are removed producing hydrogen sulphide and ammonia. These reactions occur at high temperatures and pressures in the presence of hydrogen and a catalyst.

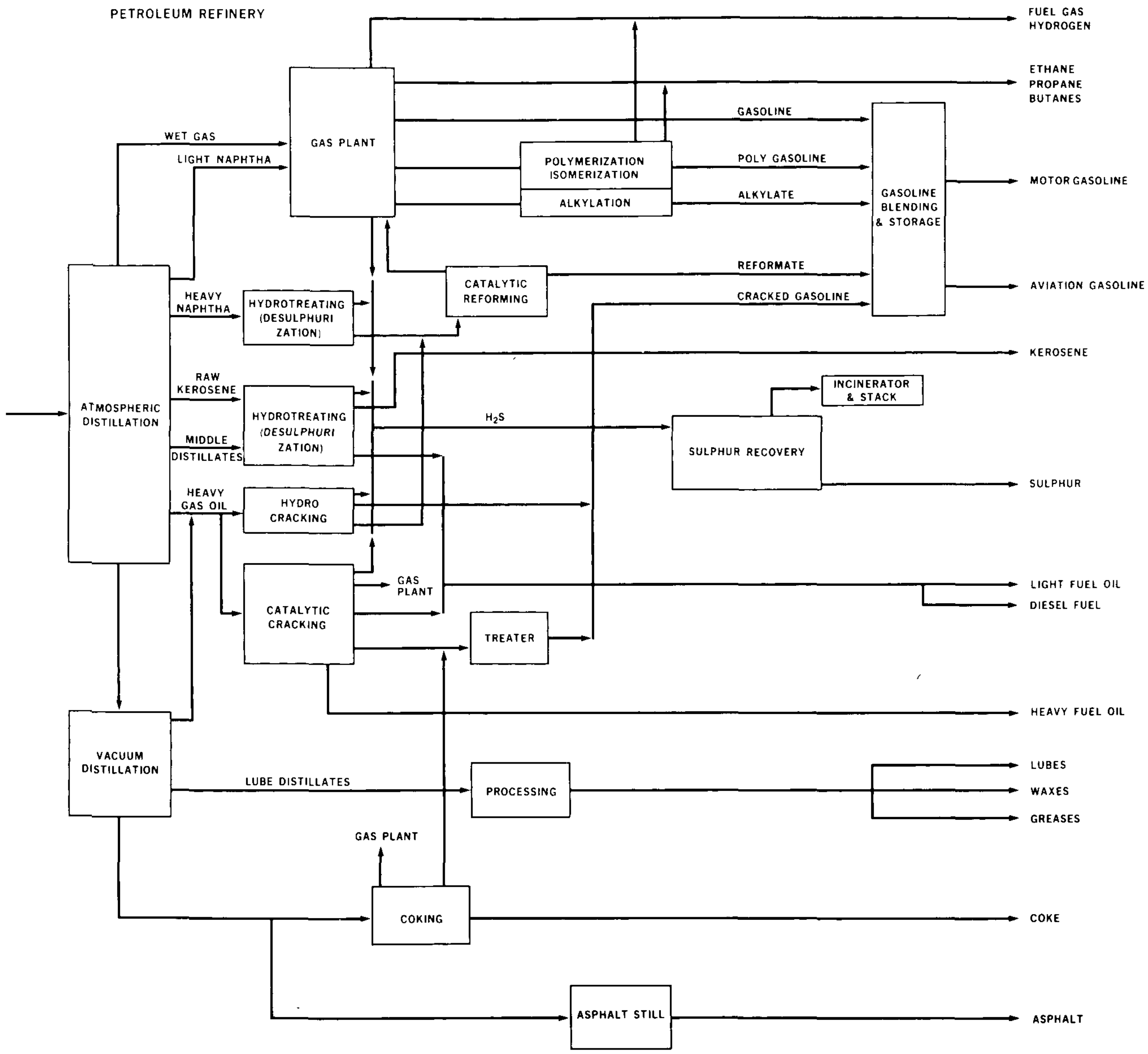


FIGURE 1 SIMPLIFIED PETROLEUM REFINERY PROCESS FLOW DIAGRAM

c) Visbreaking is an old process that was replaced by catalytic cracking and hydrocracking. Visbreaking is a mild thermal cracking operation designed to reduce the viscosity of the charge stock. The feed is heated and thermally cracked in the furnace. Cracked products are delivered to a fractionator where the low boiling materials are separated into light distillate products, while the liquid is processed in another fractionator (may be at vacuum) to recover a heavy distillate, and the residue or tar may be used for coker feed or as plant fuel.

d) Coking processes (fluid or delayed) are used only by a few refineries in Canada. Coking is a severe thermal cracking process in which the feed is held at high cracking temperature and low pressure for coke to form and settle out. The cracked products are sent to a fractionator where gas, gasoline and gas oil are separated and drawn off, and the heavier material is returned to the coker.

Rearranging Processes. The most widely used rearranging process is catalytic reforming which improves the octane quality of gasoline from crude oil. This is achieved by molecular rearrangement of naphthenes through dehydrogenation and of paraffins through isomerization and dehydrocyclization. The reformer catalyst, commonly platinum chloride on an alumina base, may also contain an activity-increasing noble metal such as rhenium. In many units the catalyst is regenerated or replaced every 6 to 12 months. In other units, the catalyst is withdrawn continuously and regenerated on-site for further use. Refineries are choosing more and more continuous reformers which do not require periodic shutdown for catalyst regeneration as do conventional reformers. The dehydrogenation and dehydrocyclization reactions produce large quantities of hydrogen as a by-product that can be used for various hydrogen treating processes.

Combining Processes. Two processes, alkylation and polymerization, are used to produce gasoline blending stocks from the gaseous hydrocarbons formed during cracking operations.

a) Alkylation is the reaction of an olefin with an iso-paraffin (usually isobutane) in the presence of a catalyst (either 98% sulphuric acid or 75 to 90% hydrofluoric acid) to produce high octane compounds known as alkylate. The reaction occurs under controlled temperatures and pressures. The reactor products are separated in a settler where the acid is returned to the reactor and the alkylate is further processed. This hydrocarbon stream is scrubbed with caustic to remove acid and organically combined sulphur, before going to the fractionation section. Isobutane is recirculated to the reactor feed, the alkylate is drawn off from the bottom of the debutanizer and the normal butane and propane are removed from the process and used as LPG. The alkylate, normal butane and propane products are also scrubbed with caustic soda.

b) Polymerization is a reaction which joins two or more olefin molecules. The use of this process has been declining since both yield and quality of the gasoline product are inferior to those derived from the alkylation process. The feed must be treated first with caustic soda to remove sulphur compounds and then with water to remove nitrogen compounds and excess caustic soda. These treatments are required to protect the catalyst in the reactor. After treatment, the hydrocarbon feed is contacted with an acid catalyst in the reactor under high temperature and pressure. The catalyst is usually phosphoric acid or, in some older units, sulphuric acid. The polymerized product from the reactor is then treated to remove traces of acid.

2.2.3 Treating.

Hydrotreating. Hydrotreating is a relatively mild hydrogenation which saturates olefins and/or reduces sulphur, nitrogen, and oxygen compounds along with halides and trace metals present in the feed, without changing the boiling range of the feed. This process stabilizes the product by converting olefins and gum-forming unstable diolefins to paraffins and also improves the product's odour and colour. Although there are various types of hydrotreating units, each has essentially the same process flow. The feed is combined with recycled hydrogen, heated to the reaction temperature, and charged to the reactor. In the presence of a catalyst (metal-sulphide), the hydrogen reacts with the oil to form hydrogen sulphide, ammonia, saturated hydrocarbons, and free metals. The metals remain on the catalyst and other products leave the reactor with the oil-hydrogen stream. The reactor products are cooled and then put into a hydrogen separator, from which hydrogen is returned to the system. The oil is sent to a fractionator for separation of light naphtha and hydrogen sulphide from the desirable feedstock.

Chemical Treating. A number of chemical methods are used throughout the refinery to treat hydrocarbon streams. They can be classified into three groups: acid treatment, sweetening processes, and solvent extraction.

a) Acid treatment consists of contacting the hydrocarbons with concentrated sulphuric acid to remove sulphur and nitrogen compounds, to precipitate asphaltic or gum-like materials, and to improve colour and odour.

b) Sweetening processes oxidize mercaptans to less odoriferous disulphides without actually removing sulphur. The most common sweetening processes are the Merox processes; others include the lead sulphide, the hypochloride, and the copper chloride processes. In the Merox process, a catalyst composed of iron group metal chelates is used in an alkaline environment to promote the oxidation of mercaptans to disulphides using air as a source of oxygen.

c) Solvent extraction involves the use of a solvent that has an affinity for the undesirable compounds and is easily separated from the product. Mercaptans are extracted using a strong caustic solution. The solvent is usually regenerated by heat, steam stripping or air blowing.

Gas Treating. These processes are used to remove the sulphur compounds from the various gaseous streams. Hydrogen sulphide (H_2S) can be extracted by an amine solution to produce a concentrated stream of H_2S that can be sent to a sulphur recovery plant.

Treatment by Physical Means. Physical methods are intermediate steps in crude processing operations and are often used to treat hydrocarbon streams or remove undesirable components. These methods include electrical coalescence, filtration, adsorption and air blowing. Physical methods are applied in desalting crude oil, wax removal, decolourizing lube oils, brightening diesel oil (to remove turbidity caused by moisture), and others.

2.2.4 Blending and Additives. A number of intermediate streams, called "base stocks" are blended to produce a product that will meet various specifications. Typical requirements may include specific volatility, viscosity, octane and other parameters. The blending operation involves the accurate proportioning of the base stocks along with proper mixing, to produce a homogeneous product.

To improve the properties of the products, a number of additives are used. Tetraethyllead, for example, is added to gasoline to increase the octane number although, with the recent regulation limiting the quantity of lead in gasoline, other additives are now being used to increase the octane of gasoline. The other additives used are anti-oxidants, anti-icing agents and metal deactivators to inhibit gum formation.

3 EFFLUENT DISCHARGE

3.1 Regulatory Requirements

To protect fish and marine organisms, the Federal Fisheries Act prohibits the deposit of deleterious substances in waters where fish are present. To this end, the Petroleum Refinery Effluent Regulations and Guidelines were issued on November 1, 1973.

The provinces of Quebec, Ontario, Alberta, and British Columbia have objectives, guidelines or regulations to supplement the federal legislation. In other provinces, effluent control is based on federal regulations and guidelines.

3.1.1 Federal Limits. The Canadian Petroleum Refinery Effluent Regulations apply to "new" refineries (i.e., those that started up on or after November 1, 1973). The guidelines apply in general to "existing" (i.e., those refineries in operation prior to this date). Regulations have the force of law, whereas guidelines are statements of practice considered to be in compliance with the "spirit of the law". Failure to comply with the guidelines is not in itself an offence but it may mean that the Fisheries Act is being transgressed.

The regulations and guidelines limit the deposits of oil and grease, phenols, sulphide, ammonia nitrogen, total suspended matter (solids) and the pH levels. Furthermore, the regulations and guidelines specify monitoring methods and reporting frequency. Limits as set in the regulations are usually more stringent than those in the guidelines except for pH levels which are the same for both. In addition, the guidelines set an acute fish toxicity limit which applies to both "existing" and "new" refineries. The intent of the regulations and guidelines is to apply a national baseline standard uniformly across Canada; however, more stringent standards may be imposed by provincial or local governments depending on local circumstances. The purpose of the federal regulations and guidelines is to ensure that all refineries in Canada apply the best practicable treatment technology (BPT) to their liquid effluents.

Effluent limitations. The limits shown in Table 1 represent the maximum allowable deposits for all parameters. The limits for oil and grease, phenols, sulphide, ammonia nitrogen and total suspended matter represent the maximum net values (i.e., the amount contributed to the refinery) excluding background concentrations in the refinery intake water. In addition, the allowable deposits expressed in $lb/10^3$ $bbl{\cdot}d^{-1}$

TABLE 1 AMOUNTS TO BE USED FOR CALCULATING MAXIMUM ALLOWABLE DEPOSITS OF SUBSTANCES (1)

	Monthly Amount lb/10^3bbl·d^{-1} (kg/10^3 m^3·d^{-1}) of crude oil		One-day Amount lb/10^3bbl·d^{-1} (kg/10^3 m^3·d^{-1}) of crude oil		Maximum Daily Amount lb/10^3bbl·d^{-1} (kg/10^3 m^3·d^{-1}) of crude oil	
Substance	Guidelines	Regulations	Guidelines	Regulations	Guidelines	Regulations
Oil and Grease	6.0 (17.1)	3.0 (8.6)	11.0 (31.4)	5.5 (15.7)	15.0 (42.8)	7.5 (21.4)
Total Suspended Matter	14.4 (41.1)	7.2 (20.5)	24.0 (68.5)	12.0 (34.2)	30.0 (85.6)	15.0 (42.8)
Phenols	0.6 (1.7)	0.3 (0.9)	1.1 (3.1)	0.55 (1.6)	1.5 (4.3)	0.75 (2.1)
Sulphide	0.2 (0.6)	0.1 (0.3)	0.6 (1.7)	0.3 (0.9)	1.0 (2.9)	0.5 (1.4)
Ammonia Nitrogen	5.0 (14.3)	3.6 (10.3)	8.0 (22.8)	5.7 (16.3)	10.0 (28.5)	7.2 (20.5)
pH					6.0 to 9.5	
Toxicity					No more than 50% fish mortality	

Note: The regulation and guideline limits are in imperial units only; metric units in brackets have been rounded (1, Schedule I).

(kg/10^3m^3·d^{-1}) of crude oil, are based on the refinery maximum design stream day crude rate which is referred to as "Reference Crude Rate" (RCR). To assess compliance, the combined actual deposits of the contaminants measured in the liquid effluent and the once-through cooling water are compared with the allowable deposits shown in Table 1.

There are three levels of allowable limits for each substance deposited per day (kg/day). The first and lowest limit is the "Monthly Amount" which represents the amount that is not to be exceeded on a daily average basis in each month. The next highest is the "One-day Amount" limit. During a month, the refinery may deposit during a single day, a substance in excess of this limit only once. An unallowable discharge is recorded for each additional day in which the deposit exceeds this limit. The third and highest allowance is the "Maximum Daily Amount"; it is a limit that should not be exceeded on any day of the month. Deposits in excess of the monthly limit (particularly if repeated) are considered to be the most severe as they may indicate an ongoing problem.

The liquid effluent and the once-through cooling water should not at any time have a pH value outside the allowable range. Fish mortality should not exceed 50% in liquid effluent and in once-through cooling water.

Monitoring requirements. Each refinery is requested to test each of the five substances three times per week (Monday, Wednesday, and Friday) and to record the amount being deposited on those days. In addition, the pH level is to be measured daily. Refineries that are subject to the regulations must report the results of these tests. All refineries are requested to perform one toxicity test each month. The results of all analysis are to be reported monthly.

Some refineries may have obtained an exemption from normal monitoring and reporting requirements as a result of approved off-site treatment of their effluent or under particular circumstances.

Stormwater. Stormwater is runoff resulting from precipitation (rain, snow, etc.) that falls on the refinery site or that originates outside the refinery but passes over or through the refinery site, and is contaminated by any of the five parameters listed in Table 1. If clean (not contaminated) runoff is segregated, it is exempted from the regulations and guidelines. In addition to the authorized deposits listed in Table 1, further deposits of oil and grease, phenols and total suspended matter are allowed for days that a refinery is discharging stormwater. These additional limits are listed in Table 2.

Reference crude rate. As previously discussed, the reference crude rate (RCR) is needed to calculate the allowable deposits and should therefore be reported by the refinery for each month. If the actual crude throughput deviates from the RCR by more than 15%, a revised RCR may be declared by the refinery and used to calculate the authorized deposits.

Refinery status. Each refinery operates under a declared status (new, existing, expanded or altered) which indicates whether a refinery falls under the regulations or the guidelines. New refineries must meet the more stringent limits and are subject to the regulations. An existing refinery is always subject to the guidelines. An existing refinery also may have an expanded or altered status. A refinery is considered "expanded" when the declared RCR is greater than 115% of the initial RCR. The portion of the revised RCR that exceeds the initial RCR is subject to the more stringent

TABLE 2 AMOUNTS TO BE USED IN CALCULATING ADDITIONAL DEPOSITS OF SUBSTANCES WHEN STORMWATER IS BEING DISCHARGED (1)

Substance	Allowance $lb/10^4 gal.\cdot d^{-1}$ $(kg/10^4\ L\cdot d^{-1})$ of storm water	Maximum Allowance per month $lb/10^3\ bbl\cdot d^{-1}$ $(kg/10^3\ m^3\cdot d^{-1})$ of crude oil	
		Guidelines	Regulations
Oil and Grease	1.0 (0.10)	50.0 (142.7)	25.0 (71.3)
Phenols	0.1 (0.010)	5.0 (14.3)	2.5 (7.1)
Total Suspended Matter	3.0 (0.30)	150.0 (428.0)	75.0 (214.0)

Note: The regulation and guideline limits are in imperial units only (1, Schedule II).

allowable deposits equivalent to new refinery limits. The replacement of a crude tower is the indicator selected to determine whether or not a refinery has an "altered" status. The portion of the RCR represented by the new tower is subject to the more stringent allowable deposits equivalent to new refinery limits.

Off-site treatment. A refinery may be given an exemption from the requirements for liquid effluent and once-through cooling water if treatment is provided in facilities outside the refinery (such as municipal sewage systems). This exemption is only granted if the off-site facility provides treatment equivalent to that required by the regulations and guidelines.

Toxicity. The acute toxicity test requirement was included in the guidelines to serve as an indicator of the presence of other parameters that are not specifically controlled such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), and heavy metals. It applies to all the refineries (including new ones). The 24-hour static bioassay test should be performed by the refinery on both the liquid effluent and the once-through cooling water. The method is described in the guidelines. The 96-hour flow-through bioassay is also described and should be conducted periodically by Conservation and Protection, Environment Canada.

The guidelines are intended to limit the quantities of contaminants discharged. This will result in the reduction of volume of effluent discharged which produces a more concentrated effluent which is more likely to be toxic to fish. To encourage the reduction of contaminants discharged but not to penalize refineries with low water consumption, a dilution of the refinery effluent is granted for those with a low water usage rate.

Analytical methodology. The regulations and guidelines also specify the test method to be used to analyze each parameter. The prescribed method is outlined in the American Public Health Association's Standard Methods for the Examination of Water and Wastewater, 13th ed. (1971) (4). If approved, an equivalent method could be used by the refinery provided the results can be confirmed by the APHA method.

3.1.2 **Provincial Limits.** Appendix A provides a summary of the federal and provincial limits for the common pollutants in refinery wastewaters.

Quebec. Refineries in Quebec are regulated by Liquid Effluent Guidelines under the Environmental Quality Act (5). Limits for deposits are essentially the same as the federal ones with a few deviations such as the federal regulations' limits for stormwater apply to both new and existing refineries and the fish toxicity test is not a requirement under Quebec's guidelines.

Ontario. Guidelines established by Ontario are generally consistent (depending on the volume of effluent discharged), with the national regulations and guidelines, although limits are expressed as concentrations. The Ontario effluent quality objectives shown in Table 3 may be superseded by site-specific requirements which are negotiated according to the sensitivity of the receiving water. These guidelines are being revised and more stringent standards for conventional pollutants and new standards for trace substances are expected.

Alberta. As in other provinces, Alberta refineries are subject to the federal regulations and guidelines as a minimum requirement. In Alberta, however, refineries that discharge their effluent into sensitive watercourses may be subject to more stringent standards which are included in the refinery permit and operating licence. The guidelines for deposits of common contaminants are provided in Appendix A. Effluent objectives for toxic elements in refinery effluents are summarized in Table 4.

British Columbia. Recommended guidelines and minimum objectives for the control of water pollution from petroleum refineries are included in the "Report on Pollution Control Objectives for the Chemical and Petroleum Industries of British Columbia" (6). The objectives, as shown in Table 5, are divided into three levels:

TABLE 3 EFFLUENT QUALITY OBJECTIVES FOR PETROLEUM REFINERIES (Ontario)

Substance	Maximum Concentration (mg/L)
Oil and Grease	10
Phenols	0.020
Suspended Solids	15
Ammonia Nitrogen	10
Chemical Oxygen Demand	200
Chromium	1
Copper	1
Nickel	1
Lead	1
Zinc	1
pH Levels	5.5 to 9.5
Toxicity	No more than 50% fish mortality for process effluent, once-through cooling water and treated stormwater.

TABLE 4 EFFLUENT OBJECTIVES FOR TOXIC ELEMENTS IN REFINERY WASTEWATER (Alberta)

Toxic Element	Net Concentrations (mg/L)*
Chromium (hexavalent)	0.30
Cyanide	0.025
Lead	0.10
Mercury	0.0005
Zinc	1.0
Nickel	1.0

* The net concentration value is calculated as:

$$\text{Net Concentration Value} = \frac{CF}{a}$$

where: C = the net concentration measured in effluent (mg/L).

F = the effluent flow rate (gal./min. per 1000 barrels of crude processed per day).

a = a constant, which defines nominal liquid effluent flow rates per 1000 barrels of crude processed per day as, 13.4 gal./min. for refineries with disposal wells, or 20 gal./min. for refineries without disposal wells.

TABLE 5 EFFLUENT QUALITY OBJECTIVES FOR PETROLEUM REFINERIES (British Columbia)[(a)]

	Discharges to Marine Water			Discharges to Freshwater		
	Level A	Level B	Level C	Level A	Level B	Level C
Oil, nonvolatile lb/1000 bbl. crude (mg/L)	--	2.80	(15)	--	2.80	(15)
Oil, total, lb/1000 bbl. crude	1.15(b)	--	--	0.58(b)	--	--
BOD, five-day, 20°C, lb/1000 bbl. crude	2.30(b)	8.0	8.0	2.30(b)	8.0	8.0
Phenols, lb/1000 bbl. crude	0.023	0.06	0.2	0.023	0.06	0.2
Sulphides and Mercaptans as S, lb/1000 bbl. crude (mg/L)	0.011	0.02	(1.0)	0.011	0.02	(1.0)
Ammonia, lb/1000 bbl. crude (mg/L)	0.576	1.87	(15)	0.576	1.87	(15)
Suspended solids, mg/L(c)	20	20	30	20	20	30
Settleable solids, mg/L	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Floatable solids	(d)	(d)	(d)	(d)	(d)	(d)
Total solids, g/L	3.0(e)	3.0(e)	3.0(e)	1.5	1.5	2.0
Cyanide, mg/L	0.10	0.10	0.20	0.10	0.10	0.20
Chromium, total, mg/L	0.2	0.2	0.2	0.2	0.2	0.2
Lead, total, mg/L	0.2	0.2	0.2	0.2	0.2	0.2
Zinc, total, mg/L	0.2	0.2	0.3	0.2	0.2	0.2
Copper, total, mg/L	0.1	0.1	0.1	0.1	0.1	0.1
Nickel, total, mg/L	0.2	0.2	0.2	0.2	0.2	0.2
Phosphate (as P), mg/L	3.0	3.0	3.0	1.0	1.0	3.0
Dissolved oxygen, mg/L	> 1.0	> 1.0	--	5.0	> 1.0	> 1.0
pH	6.5 to 8.5	6.5 to 9.0	6.5 to 9.0	6.5 to 8.5	6.5 to 8.5	6.5 to 9.0
Temperature, °F maximum	90	90	90	90	90	90
Turbidity, J.T.U.	15	15	25	10	10	15
Toxicity (f)	75	50	5	100	75	5
Process effluent volume (g) (Imp. gal·min^{-1}/1000 bbl·d^{-1})	8.0	13.0	--	8.0	13.0	--

(a) These objectives include process effluent and storm runoff from the processing area. Excluded are ballast water from ships, once-through cooling water used for indirect cooling, and storm runoff from dyked tank storage areas and undeveloped areas.

(b) These values are tentative and subject to review.

(c) Not applicable to discharges to exfiltration ponds.

(d) Negligible.

(e) Depends upon the nature of solids other than normal marine composition.

(f) 96-h TLm Static bioassay on salmonid species, expressed as percent by volume of effluent in receiving water which is required to give 50% survival over 96 hours.

(g) Normal dry weather flow (does not include storm runoff). Not a restrictive objective. If effluent volume discharged is greater, concentration must be reduced proportionately.

Level A:	the objectives for discharges from new and proposed refineries and, within the limits of the best practicable technology, discharges from existing refineries through planned improvements;
Level B:	the intermediate objectives for discharges from all existing refineries, to be achieved within a period of time specified by the Director of the Pollution Control Branch, and for discharges from existing refineries that may be increased in quantity or altered in quality as a result of process expansion or modification; and
Level C:	the immediate objectives for all existing refineries, to be achieved within a minimum technically feasible period of time.

In general, the daily average limits are stricter than the federal monthly amounts. In addition to common pollutants, British Columbia specifies a number of other parameters, including metals. The fish toxicity test required in the 96-hour static bioassay with 50% survival. The refinery effluent may be diluted to perform the bioassay test, and the level of dilution is set according to the refinery status (levels A, B, C, discharging into marine water or freshwater).

3.2 Wastewater Generation

Refinery wastewater contaminants originate from the following sources:

1) crude oil;
2) refinery intake water;
3) refinery stormwater;
4) ballast water;
5) sanitary wastes;
6) process chemicals and catalysts;
7) reaction production from conversion units; and
8) chemical additives.

Crude oil is a complex mixture of hydrocarbons, but it also contains impurities. These are in the form of organic compounds of sulphur, nitrogen, oxygen, and a number of metals. In addition, inorganic salts are contained in crude oil in the form of emulsified brine. To minimize the formation of hydrochloric acid in the distillation tower, crude oil should be desalted, and in some cases, neutralized with caustic soda and ammonia. To reduce the salt, crude oil is contacted with water which is emulsified in the crude, and the mixture is passed through a chemical or electrostatic desalter. In the desalter, the oil phase is separated from the brine. The water phase will contain oil, desalting chemicals, dissolved salts and suspended solids. After stripping, sour water is generally used as wash water in the desalter to reduce freshwater consumption.

Intake water will contain a variety of impurities depending on the location of the refinery (on river, ocean, upstream industry). The water will usually require treatment prior to being used in boilers and cooling towers. Water hardness and silica content will determine the degree of treatment and the quantity of blowdown from these systems.

Stormwater that falls on the refinery site collects silt and any spilled oil from the refining processing and tank farm areas. Stormwater may also contain traces of phenols and other contaminants.

Ballast water is carried in navigational vessels to provide stability. This also includes water used for cargo or ballast tank cleaning. Refineries that ship products by marine tanker receive the ballast water before loading the vessel. The water generally contains oil, phenols and trace amounts of suspended solids and total dissolved solids.

Sanitary wastes generated by personnel working in refinery office buildings, control rooms and laboratories are collected and either treated on-site or sent to the municipal sewer system. The contribution to the total refinery BOD and suspended solids from this source is small.

Process chemicals and catalysts are used in a refinery and can lead to water contamination. Process chemicals may include caustic soda, sulphuric and phosphoric acids, amines, sulpholane, furfural, glycol, ammonia, detergents for chemical cleaning, process additives such as antifoam agents, corrosion inhibitors (chromium and zinc), lime and water softening chemicals for boiler feed water preparation, and nutrients for biotreater operation. In processes such as the wet treating of products, some of these chemicals enter the refinery sewer.

Catalysts are used to facilitate the conversion of hydrocarbons into more valuable forms. The major catalysts that can lead to water contamination are:

1) sulphuric acid that is used in alkylation (a source of sulphonates, sulphates, organic esters and sulphuric acids);

2) hydrofluoric acid used in alkylation (can produce fluorides);

3) phosphoric acid used in polymerization (produces phosphates and phosphoric acid); and

4) wet-treating catalysts (Merox, Mercapfining ...).

Reaction products from conversion units generate contaminants that end up in the refinery's liquid effluent. These processes include: hydrotreating, thermal cracking/vis-breaking, coking, catalytic cracking, hydrocracking and reforming. Table 6 summarizes the various water contaminants that can be generated by these processes.

TABLE 6 CONVERSION PROCESSING UNITS THAT GENERATE WATER CONTAMINANTS

Process	Water Contaminant
Hydrotreating	- hydrogen sulphide, ammonia
Thermal Cracking/Visbreaking	- ammonia, nitrogen compounds, hydrogen sulphide, mercaptans, naphthenic acids, organic acids
Catalytic Cracking	- phenols, hydrogen sulphide, carbon disulphide, disulphides, triophenes and carbonyl sulphides, ammonia, cyanides and cyanates
Reforming	- benzene, toluene, xylene can show up as COD in gasoline storage tank water drainings
Alkylation	- sulphates, alkyl sulphonates and hydrofluoric acid

Chemical additives are used in the products to enhance their quality and meet specifications. These can include: corrosion inhibitors, anti-knock compounds, anti-icing compounds, and antioxidants. The additives may enter into the effluent water as a result of spills from chemical storage.

In summary, the major sources of water contamination are: crude desalter/crude distillation; sour condensates from hydrotreating and cracking units; boiler feed and cooling water blowdown; and process wash waters. The significant contaminants are: oil and grease, phenols, COD, sulphides, ammonia, and suspended and dissolved solids. Minor contaminants include: cyanides, fluorides, alkylsuphonates, chromates and heavy metals (iron, zinc, copper, lead, nickel).

3.3 Wastewater Treatment

As intended by the federal regulations and guidelines, most refineries in Canada apply best practicable treatment technology to their liquid effluents, or in some cases, a variation thereof. The best practicable treatment is described in the regulations and guidelines as:

a) sour water stripping for ammonia and sulphide removal;
b) primary separation (such as an API separator) followed by;
c) intermediate treatment (such as air flotation) followed by;

d) secondary treatment (such as biological treatment);

e) final effluent clarification if required; and

f) segregation and treatment of stormwater if required.

In addition, good housekeeping and maintenance, safe disposal of spent chemicals and adequate facilities for ensuring smooth, continuous operation of the treatment system are recommended for achieving an acceptable effluent.

Currently, 76% of the refineries in Canada treat their effluents with secondary or tertiary treatment systems. This figure includes refineries that have primary or intermediate treatment systems on-site but, in addition, send their effluents for further treatment (biological) to the municipal sewage system.

A brief description of the various unit processes used by the refineries for wastewater treatment follows. The efficiency of the various units in reducing the contaminants is shown in Table 7.

TABLE 7 EXPECTED PERCENT REDUCTION THROUGH WASTE TREATMENT SYSTEMS (7)

Treatment Method	Oil	Phenol	pH	Total Sulphides	Ammonia Nitrogen	Filtered Suspended Solids	BOD_5	COD	TOD	Cyanides	Lead	Chromium	Toxicity
Foul Condensate Stripper	NA	10 to 30%	I (1 to 2 points)	96 to 99.8%	69 to 96%	NA	NA	R	R	75 to 90%	NA	NA	
API Separator	60 to 99%	R	NA	R	NA	10 to 50%	5 to 35%	5 to 40%	5 to 40%	NA	R	R	NA
Crude Desalter	NA	70 to 90%	NA	NA	NA	NA	NA	NA	NA	NA	R	NA	
Air Flotation and Flocculation	75 to 90% 50 to 90% (emulsified)	R	I (slightly)	R	R	50 to 90%	10 to 60%	10 to 50%	10 to 50%	NA	NA	R	NA
Sludge Beds	NA	NA	NA	NA	NA	90 to 99%	NA	NA	NA	NA	NA	NA	
Storm Retention Ponds	50 to 95%	R	NA	NA	NA	80 to 99%	R	R	R	NA	NA	NA	NA
Biological Unit	50 to 80% (emulsified)	97 to 99%	R (by 1 point)	90 to 99%	R	I	60 to 85%	30 to 70%	30 to 70%	65 to 99%	NA	NA	R
High Rate Sand Filtration	70 to 80%	NA	NA	NA	NA	50 to 99%	R	R	R	NA	NA	NA	
Ballast Water Tanks	60 to 99%	R	NA	R	NA	10 to 50%	R	R	R	NA	R	NA	NA
Activated Carbon or Ozonation	50 to 90% (emulsified)	80 to 99%	NA	80 to 99%	10 to 30%	NA	50 to 90%	50 to 90%		80 to 99%			R

NA - Not available; R-reduced; I-increases

3.3.1 Primary Treatment. Primary treatment systems include: sulphide and ammonia stripping, gravity separation, liquid-liquid extraction, filtration and pH control.

Stripping of sour water is performed used to reduce sulphide, ammonia and, to a lesser degree, phenols collected from various refining processes. The stripping process consists of a trayed or packed tower supplied with 50 to 240 kg of steam for each cubic metre of sour water stripped. The stripped gases may be incinerated or fed to the sulphur recovery plant. In the latter case, a two-stage stripping process may be required to reduce the ammonia content of the hydrogen sulphide stream. The removal of ammonia will reduce problems associated with the presence of ammonia in the feed gas of the Claus sulphur recovery unit.

Gravity separation systems remove free oil and suspended solids from wastewaters. The system may consist of a tank (such as the ballast water tank), a pond (as the storm water retention pond) or a lagoon equipped with oil skimmers. Most refineries use an American Petroleum Institute (API) separator; however, use of the tilted-plate separator is increasing. The API separator is a large basin which allows free oil to rise to the surface to be reclaimed, and solids to fall to the bottom for removal and disposal. Many important design parameters govern the effectiveness of the API separator, including the water temperature, the density and size of oil droplets and the type of solids in the water. The tilted-plate separator is made of several corrugated plates tilted at a 45° angle. As the wastewater flows between plates oil droplets collect on the underside and rise to the top while solids settle on the lower side and settle to the bottom.

The main application of liquid-liquid extraction in refineries is for the extraction of phenolic compounds from various condensate waters. The extraction takes place in a crude oil desalter where water (usually stripped sour water) is mixed with crude oil and heated in the crude desalter. The emulsion formed is broken by electrical or chemical (caustic soda addition) means. Since phenols have an affinity to the oil phase, they are extracted from the water phase whereas crude oil is cleared of the silt and chlorides.

High-rate sand filtration which operates under pressure serves mainly as a polishing device and is capable of removing all suspended solids down to a few micrometres in size, limited amounts of colour agents and traces of oil.

The pH of refinery wastewater needs to be controlled because it would be detrimental to subsequent biological processes or receiving waters. In some cases, phosphoric acid or ammonia is added to control pH and at the same time to supply nutrients for subsequent biological treatment.

3.3.2 Intermediate Treatment. Intermediate treatment systems include: flotation, coagulation-precipitation and equalization.

Flotation is used to further remove undissolved oil and suspended solids from API separator effluents prior to discharge or biological treatment. Other contaminants such as phenols, BOD, and sulphides will also be reduced to a certain extent. The process may either be dissolved air or induced air flotation. In dissolved air flotation, wastewater is kept under pressure (275 to 350 kPa) and compressed air is added so that the air will dissolve. The wastewater then passes through a pressure-reducing valve, forming minute bubbles in the water. The bubbles attach themselves to the oil and suspended particles in the wastewater and rise to the surface as froth which is continuously skimmed for treatment or disposal. To improve the effectiveness of the flotation unit in removing oil emulsions, chemical flocculating agents are added. In the induced-air process, the air is introduced by specially designed agitators or diffusers and is dispersed through the wastewater.

Equalization ponds are generally used ahead of biological oxidation units to reduce fluctuations in flow rates and loadings, since biological processes are sensitive to shock loading.

3.3.3 Secondary Treatment. Secondary treatment systems are biological oxidation processes which include: activated sludge, trickling filters, waste stabilization ponds, and aerated lagoons. The purpose of these treatment systems is to remove phenols and reduce BOD (including biodegradable priority pollutants) in the wastewaters. This is achieved by bacteria which consume the organic material contained in the wastewater and convert it into carbon dioxide and water. Oxygen and nutrients are required, and new bacteria are produced continuously. The biological mass of bacteria is then separated from the treated wastewater by settling, and then recirculated to the incoming waste.

Activated sludge is an aerobic (in the presence of oxygen) biological treatment process in which microorganisms (in high concentrations) are suspended in wastewater within a holding tank. Oxygen is introduced by mechanical aeroator or diffused air systems. The treated effluent then passes through a sedimentation tank before being discharged to the receiving water or in some cases to further treatment. The activated sludge is returned to the reaction tank or disposed of (usually by landspreading).

Trickling filters consist of a fixed growth of aerobic microorganisms contained in a porous bed, normally made of broken rock or coarse aggregate. Bacteria grow on the surfaces of the bed media and remove organic material from the wastewater by adsorption, bioflocculation, and sedimentation. Oxygen is supplied for rapid metabolism of the removed organic matter. The effluent is then clarified in a sedimentation tank.

Waste stabilization ponds and aerated lagoons are large shallow ponds in which dilute concentrations of microorganisms are mixed with wastewater. Oxygen is supplied by surface diffusion, mechanical aeration units, or by the photosynthetic action of the algae present in the pond, and is consumed by bacteria in the aerobic degradation of organic matter. Unlike the activated sludge process, the effluent from the stabilization pond or aerated lagoon is not settled prior to discharge because of the low concentration of biological solids maintained in the system. In addition, the biological solids are not recirculated.

3.3.4 **Tertiary Treatment.** Tertiary systems are used only by a few refineries in Canada. The primary purpose of tertiary treatment is to remove organic matter, taste and odour producing substances, and dissolved inorganic substances. Activated carbon, filtration and chemical oxidation (such as ozonation) can be used effectively to remove these materials.

3.4 Effluent Discharges and Compliance with the Federal Regulations and Guidelines

This section presents the status of compliance of petroleum refineries in Canada with respect to the Federal Petroleum Refinery Effluent Regulations and Guidelines. A detailed analysis has been made for the 1987 discharge data. The information provided by the refineries was assessed and compiled into annual compliance reports by Environment Canada regional offices. This national report is a summary of the regional reports.

The following points should be taken into consideration before interpreting the results that are presented in this section or those shown in Appendix B.

1. The actual annual deposits found in Appendix B and presented in this section were calculated by taking the arithmetic mean of the monthly amounts discharged during the year. The monthly amounts vary considerably from one month to another; therefore, the annual average alone does not accurately reflect the situation. To provide a better appreciation of the annual deposit, its standard deviation expressed in percentage is also given in Appendix B. In interpreting the results, the deviation should be taken into consideration.

2. There is a great disparity between refineries in the number of tests reported. This is because the refineries do not submit all the tests required. In addition, some refineries have been given an exemption from the normal reporting requirements.

This disparity greatly affects the assessment of the number of deposits in excess of the limits and has an impact on the accuracy of the monthly amounts which are the average of the reported daily deposits. The performance of each refinery is best assessed by comparing the percentages of time that the refineries were not in compliance. This value takes into account the number of tests reported and, therefore, provides a good basis for comparison (Appendix B).

3. The analytical test method prescribed in the regulations and guidelines for analyzing an effluent sample is the one described in the 13th edition of the APHA Standard Methods (4), or any proven equivalent method. Many refineries are now using the 14th and the 15th edition (8,9), of the APHA method as per provincial requirements. The 15th edition may provide higher results than the 13th edition for some parameters. Since not all the refineries are using the same method, direct comparisons are very difficult.

3.4.1 National Assessment. In 1987, 29 refineries were operating in Canada. Sixteen had an "existing" status and six had an "expanded" status as defined in the guidelines. The other seven refineries were new and subject to the regulations.

One refinery has come on line since 1984: Newfoundland Energy Ltd -- Come-by-Chance, NFLD, in June 1987. Since 1984, only one refinery was shut down: Gulf Canada -- Montreal, Quebec, in January 1986.

In 1987, six refineries (in the Pacific & Yukon, and the Western & Northern regions) provided primary, intermediate or secondary treatment on-site, and further treatment (sometimes secondary) off-site. Two refineries (Husky -- Lloydminster and Turbo -- Balzac) used deep-well injection for disposing of all their treated effluents except stormwater and, therefore, were subject to the regulations and guidelines for their stormwater discharges only. One additional refinery (Shell-Bowden) did not have any discharge in 1987. The remaining refineries had primary and/or secondary treatment systems and discharged their treated wastewaters to surface waters. Four refineries in Ontario and Quebec also treat the effluents of associated petrochemical plants (not subject to the refinery regulations and guidelines) and one refinery (in B.C.) treats the effluent of an associated natural gas plant.

On average, 65% of the tests requested in the regulations and guidelines were reported for 1987. Different provincial reporting requirements are responsible for this situation. Two regions which contributed to this low average were the Pacific & Yukon which reported only 24% of the tests and the Western & Northern region which reported 43%.

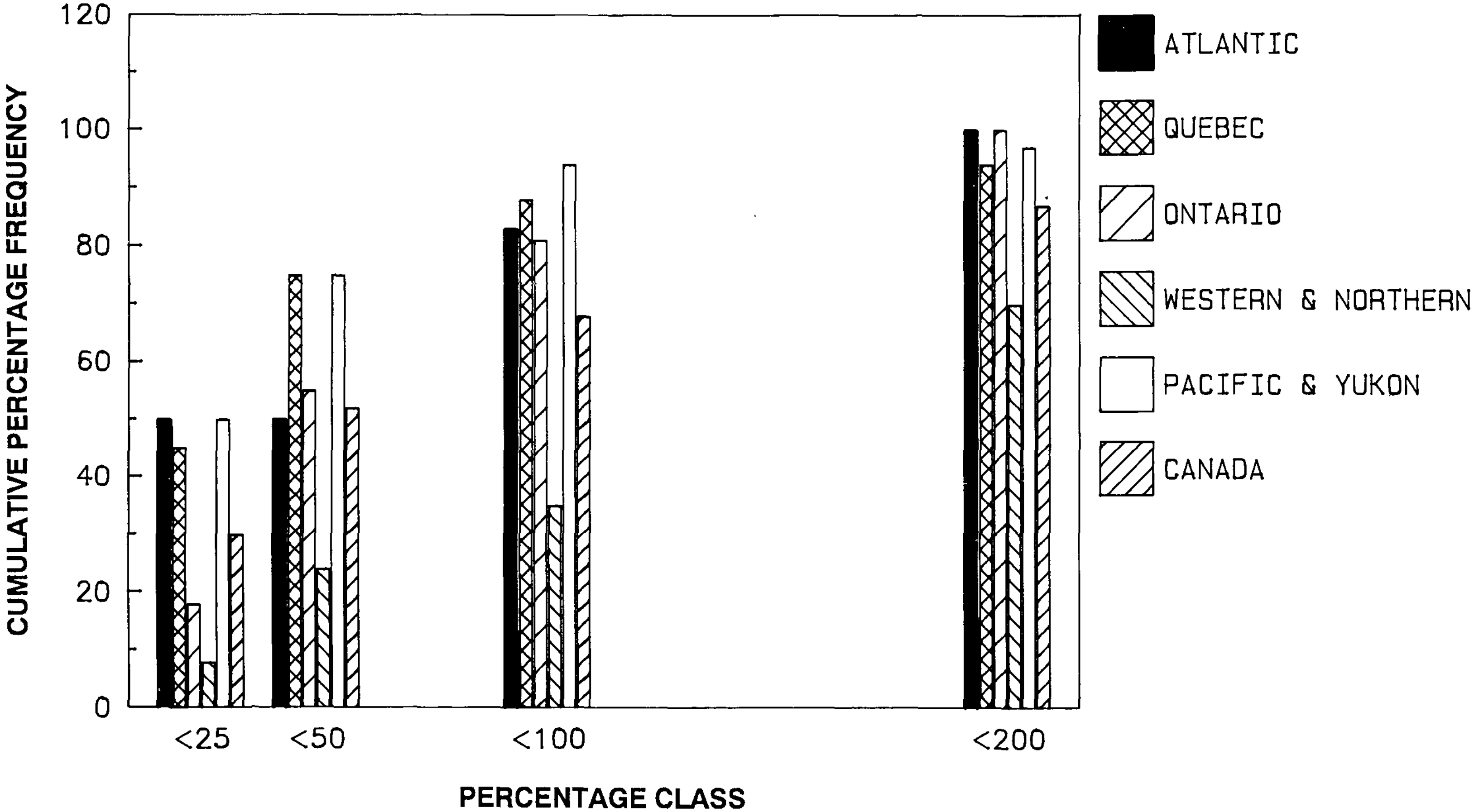
The performance in each region in 1987 is summarized in Appendix B. It should be noted that the authorized deposits and guideline deposits apply only to individual refinery effluents. Therefore, there is not an "authorized level" for a region, or for

Canada. These calculated deposits, however, are useful in assessing the performance of the refineries as a whole within the various regions or within the country. Furthermore, the "authorized deposits" and "guideline deposits" presented in the figures in this section and the tables in Appendix B were obtained by computing the yearly average of the authorized monthly amounts (calculated according to the regulations and guidelines). These authorized and guideline deposits are compared to the "actual deposits", which are a yearly average of the arithmetic monthly average of daily deposits. The refineries are not required to meet these yearly averages; they were calculated to provide an indication of the refineries' annual performance.

1987 National and Regional Performances. The overall national performance in 1987 was in compliance more than 94% of the time with the monthly amounts, 99% with the one-day amounts, 99% with the maximum daily amounts, and 92% with the stormwater limits. Exceeding the monthly limits is considered more serious than exceeding the other limits. A regional breakdown of compliance with the monthly amounts of the guidelines by parameter is provided in Table 8. The Western & Northern region exceeded the limits most frequently. The Atlantic region had the best level of performance complying with the monthly amounts followed closely by the Pacific & Yukon and Ontario regions. The parameter of most concern for the refineries under the guidelines was total suspended solids. Sulphide limits were generally met most frequently by the refineries that are subject to the guidelines. Figure 2 provides an indication of the severity of the deposits

TABLE 8 PERCENT COMPLIANCE OF REFINERIES IN EACH REGION WITH MONTHLY AVERAGE LIMITS AS SET IN THE GUIDELINES (1987)

	% of Time in Compliance with the Guidelines					
Region	Oil and Grease	Total Suspended Solids	Phenols	Sulphide	Ammonia Nitrogen	Average
Atlantic	100	89	97	100	100	98
Quebec	92	78	97	94	94	91
Ontario	98	88	100	98	98	97
Western & Northern	86	82	70	98	73	82
Pacific & Yukon	96	92	99	100	97	97
Canada	95	87	94	98	93	93



Note:

Cumulative Percentage Frequency= $\dfrac{\text{number of discharges that exceeded the limits by a specific \% class}}{\text{total number of discharges in excess of the limits}}$

Percentage Class= $\left[\dfrac{\text{discharge that exceeded the limit - limit}}{\text{limit}}\right] \times 100$

FIGURE 2 FREQUENCY DISTRIBUTION OF THE PERCENTAGE OF DISCHARGES IN EXCESS OF THE MONTHLY AMOUNTS LIMITS that exceeded the limits of the monthly amounts. The y-axis represents the distribution of deposits (monthly average) that exceeded the monthly amounts; the x-axis indicates by how much these limits were exceeded. For Canada, 51% of the deposits that exceeded the monthly amounts were less than 50% above the limits and 13% were more than 200% above the limits. Fifty percent of the Atlantic, Pacific & Yukon regions deposits and 44% of the Quebec region deposits that exceeded the limits were less than 24% above the limit. The Atlantic and Ontario regions did not have any deposits that were more than 200% above the limits. The Western & Northern region had the highest number of deposits (30%) that were more than 200% above the limits.

Refinery Performance. Of the 26 refineries that were assessed in 1987 (excluding the two refineries with deep-well injection and the one with no discharge), 9 refineries were in compliance with all the limits more than 99% of the time and seven were in compliance between 95% and 99% of the time. Of the remaining 10 refineries, three had further treatment provided off-site. The three refineries that had the lowest performance in relation to the monthly amounts were: the Co-op refinery in Regina (60% of the time in compliance; Newfoundland Energy Ltd. -- Come-by Chance (70%), and Esso -- Norman Wells (77%). The Co-op effluent receives further treatment at the municipal treatment plant which, under normal conditions, would reduce the deposits to an acceptable level. It is suspected, however, that with levels as high as the 1987 deposits, th efficiency of the off-site treatment would be reduced. The Newfoundland refinery had several problems and fires from June to December 1987 and the company only started discharging in November 1987. At Esso-Norman Wells more than 50% of the violations are due to high levels of suspended solids in the intake water from the Mackenzie River. The overall performance of refineries in each region is provided in Table 9. A more detailed analysis of the performance of each refinery and each region is provided in the next section.

Trends in National Performance and Annual Deposits. The overall national compliance performance has been slowly improving since 1980. The percentage of time the Canadian refineries were in compliance with the monthly amounts went from 91% in 1980, to 92% in 1983, and finally 94% in 1987.

The national annual average of the deposits (expressed as $kg/10^3\ m^3$ of crude oil) from 1972 to 1987 are presented in Figures 3 to 7. The downward trend for discharge levels continued in 1987 with improvements over the 1983 levels for all parameters. Since 1980, all the annual deposits have been below the authorized levels. In Ontario, the refineries' intake water contains a higher level of sulphide than the treated effluent, leding to a negative value when the refinery net loading is calculated.

TABLE 9 OVERALL REFINERY PERFORMANCE WITH FEDERAL REGULATIONS AND GUIDELINES

Refinery/Region	Performance: % of Time in Compliance M	O	N	S	% of Tests Reported	Comments*
Atlantic						
. Esso Petroleum (Dartmouth)	95.0	99.9	98.9	-	100	
. Irving (St. John)	100	100	99.7	-	99.9	
. Texaco (Dartmouth)	100	100	99.8	-	94.6	
. Newfoundland Energy Ltd. (Come-by Chance)	70	94.3	95.9	-	68	subject to regulations
. Region	96.8	99.6	99.4	-	97.1	
Quebec						
. Petro-Canada (Pointe-aux-Trembles)	93.3	98.0	98.9	-	98.3	
. Shell (Montreal)	83.3	96.6	97.6	-	99	
. Ultramar (St-Romuald)	96.7	99.7	98.6	-	97.7	
. Region	91.1	98.1	98.4	-	98.5	
Ontario						
. Esso (Sarnia)	100	100	100	-	81.9	
. Shell (Corunna)	88.1	98.6	97.8	-	60	
. Petro-Canada Trafalgar (Oakville)	98.3	100	100	-	86.4	
. Petro-Canada Clarkson (Mississauga)	100	99.4	99.3	97.2	99.8	
. Suncor (Sarnia)	96.7	99.3	99.3	-	78.7	
. Petrosar (Corunna)	100	100	100	-	86.3	subject to regulations
. Texaco (Nanticoke)	100	100	100	100	99.4	subject to regulations
. Region	97.5	99.7	99.6	98.6	84.7	
Western & Northern						
. Petro-Canada (Edmonton)	100	100	100	-	54	
. Petro-Canada (Moose Jaw)**	95.0	-	-	-	6.9	
. Esso Petroleum (Norman Wells)	76.7	93.7	93.2	-	97.8	
. Shell (Bowden)	-	-	-	-	-	no discharge
. Co-op (Regina)***	60.0	-	-	-	21	
. Husky (Lloydminster)	-	-	-	100	-	deep-well injection; subject to regulations for stormwater only
. Esso Petroleum (Edmonton)	100	100	100	-	53.9	subject to regulations
. Turbo (Balzac)	-	-	-	100	-	deep-well injection; subject to regulations for stormwater only
. Shell (Scotford)	100	100	100	-	65.5	subject to regulations
. Region	88.2	98.6	99	100	43	
Pacific & Yukon						
. Esso Petroleum (Ioco)	100	100	94.3	52.8	24	
. Petro-Canada (Port Moody)	100	100	100	100	27.1	
. Husky (Prince George)	100	100	98.5	-	22.5	
. Petro-Canada (Taylor)	100	100	99.7	93.3	27.1	
. Shell (Burnaby)	90.0	100	99.7	92.9	25.4	
. Chevron (North Burnaby)	90.1	99.5	95.9	97.2	20.9	
. Region	96.8	99.9	98.2	86.1	24.5	
National	94.3	99.4	99.2	91.6	65.1	

* Refineries were subject to the guidelines if not otherwise specified under Comments.
** Company supplied only monthly averages. Thus, unable to determine daily compliance.
*** Monthly amounts based on tri-monthly average of discharge effluent.
M : monthly amount; O : one-day amount; N : maximum daily amount; S : stormwater limits.

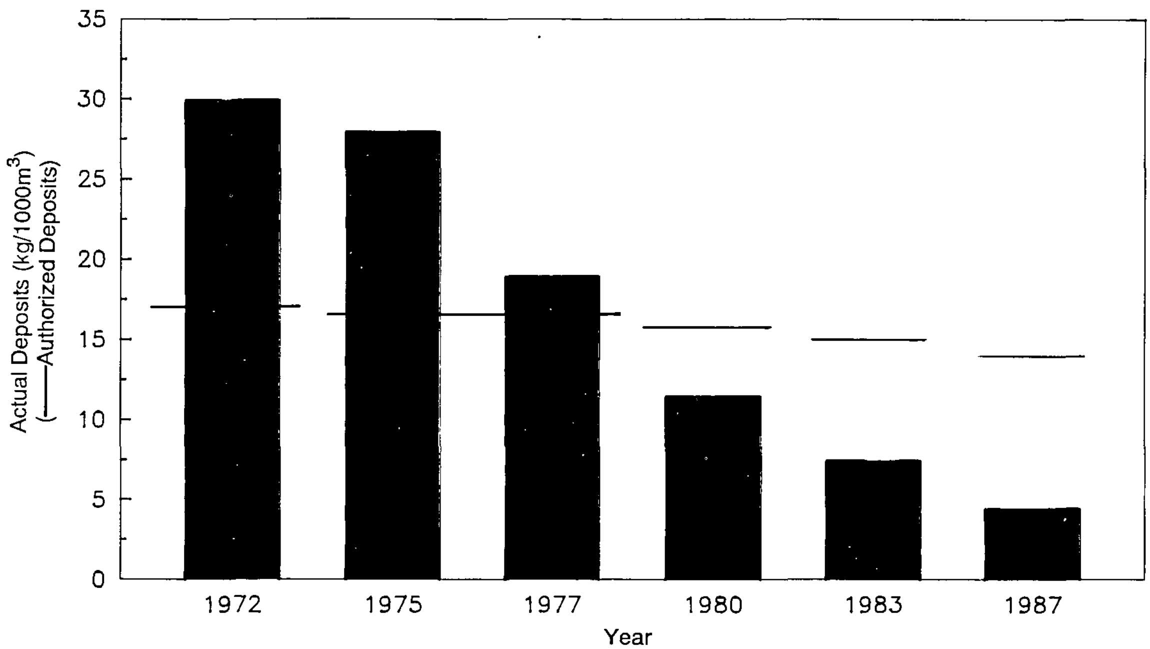


FIGURE 3 AVERAGE ANNUAL DISCHARGES OF OIL AND GREASE (National - 1972 to 1987)

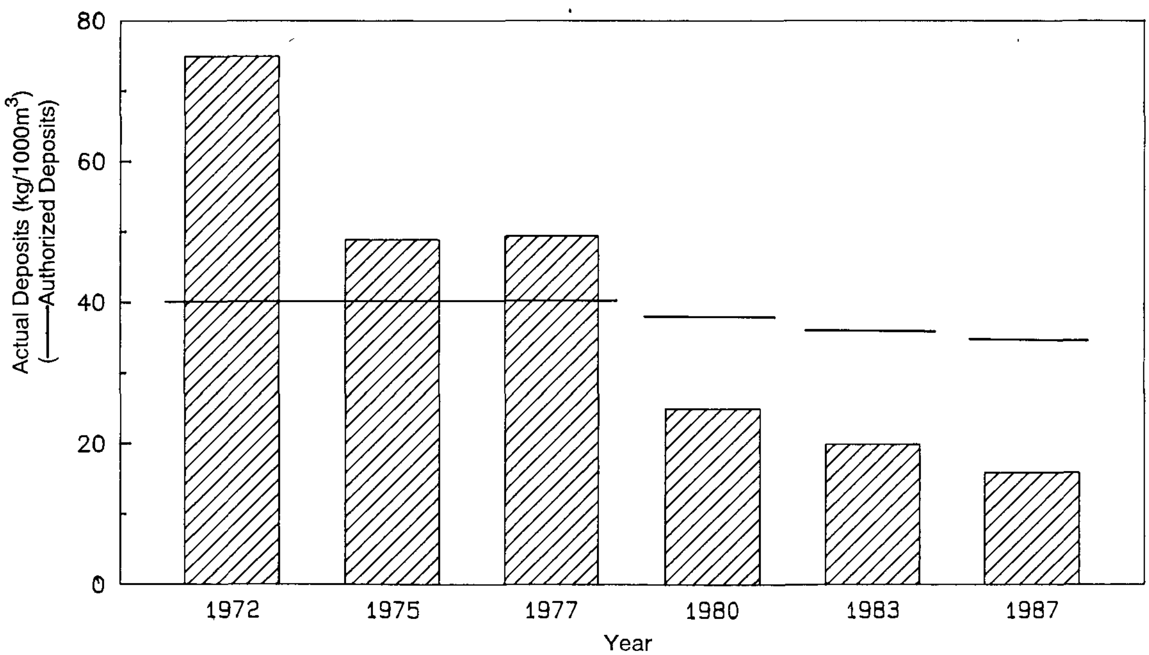


FIGURE 4 AVERAGE ANNUAL DISCHARGES OF TOTAL SUSPENDED SOLIDS (National - 1972 to 1987)

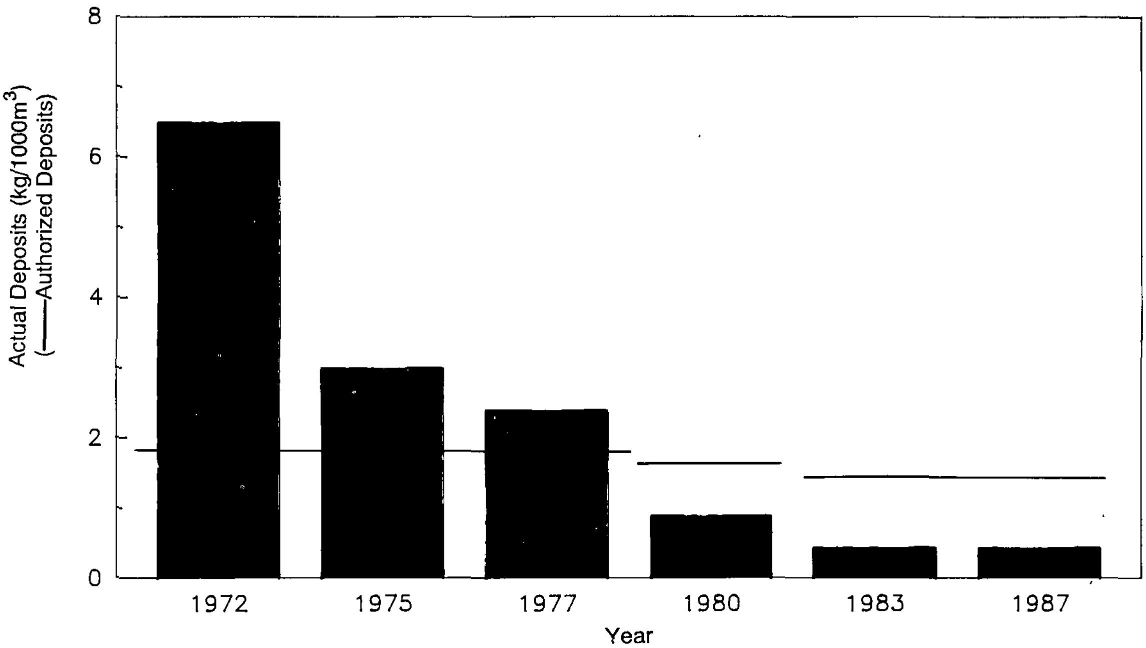


FIGURE 5 AVERAGE ANNUAL DISCHARGES OF PHENOLS (National - 1972 to 1987)

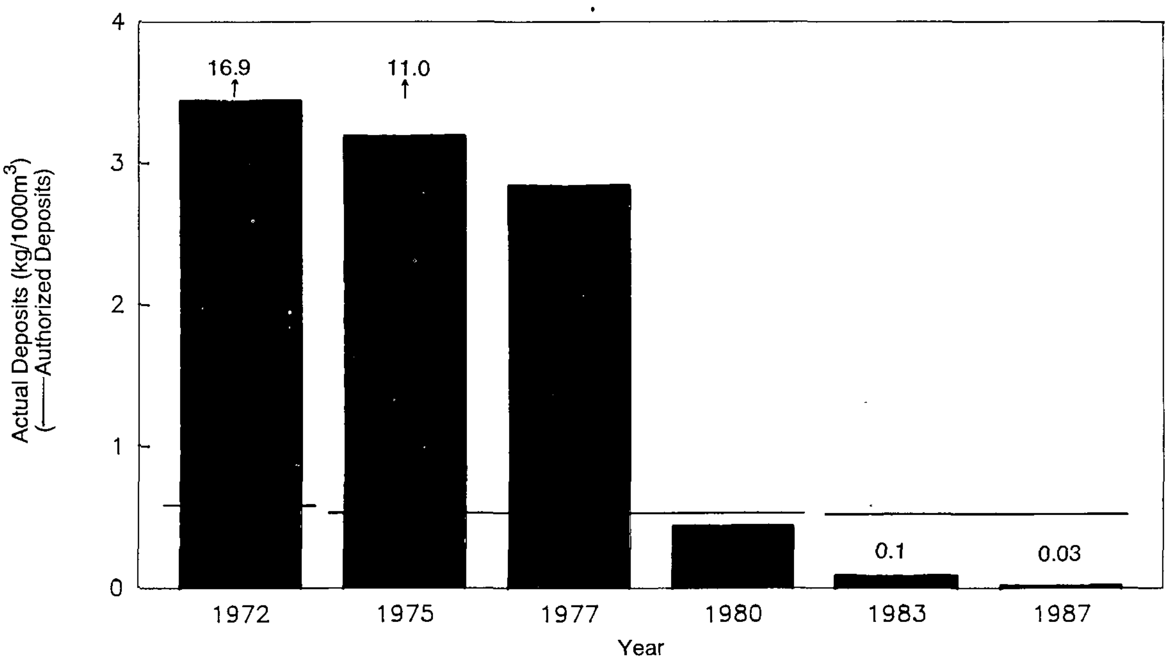


FIGURE 6 AVERAGE ANNUAL DISCHARGES OF SULPHIDE (National - 1972 to 1987)

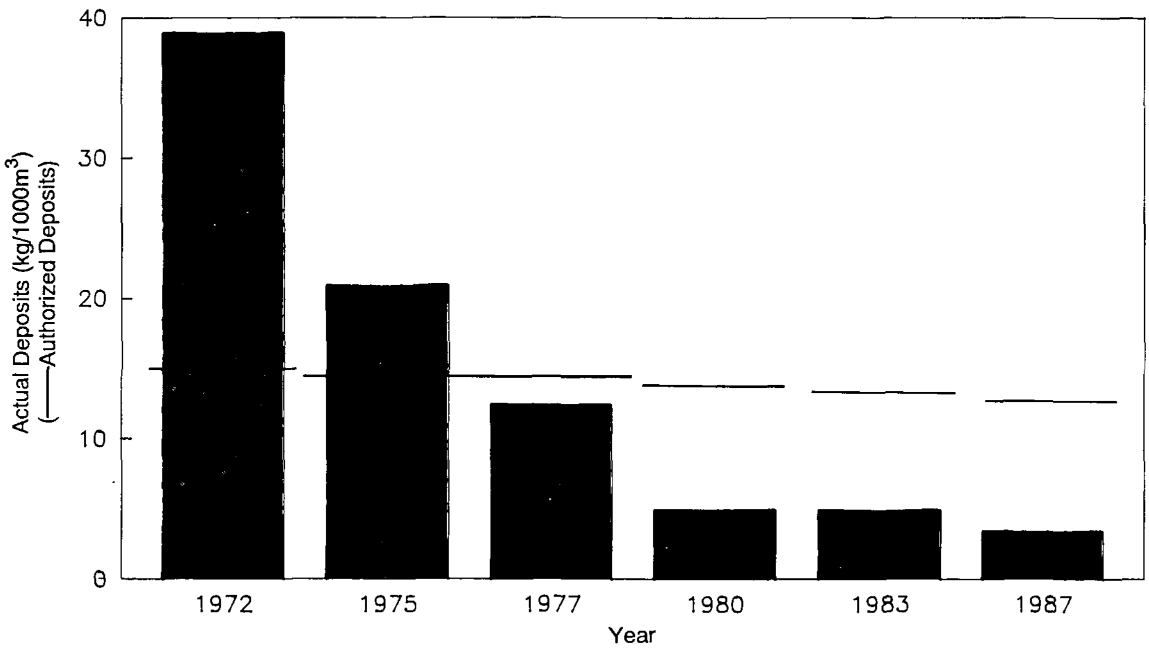


FIGURE 7 AVERAGE ANNUAL DISCHARGES OF AMMONIA NITROGEN (National - 1972 to 1987)

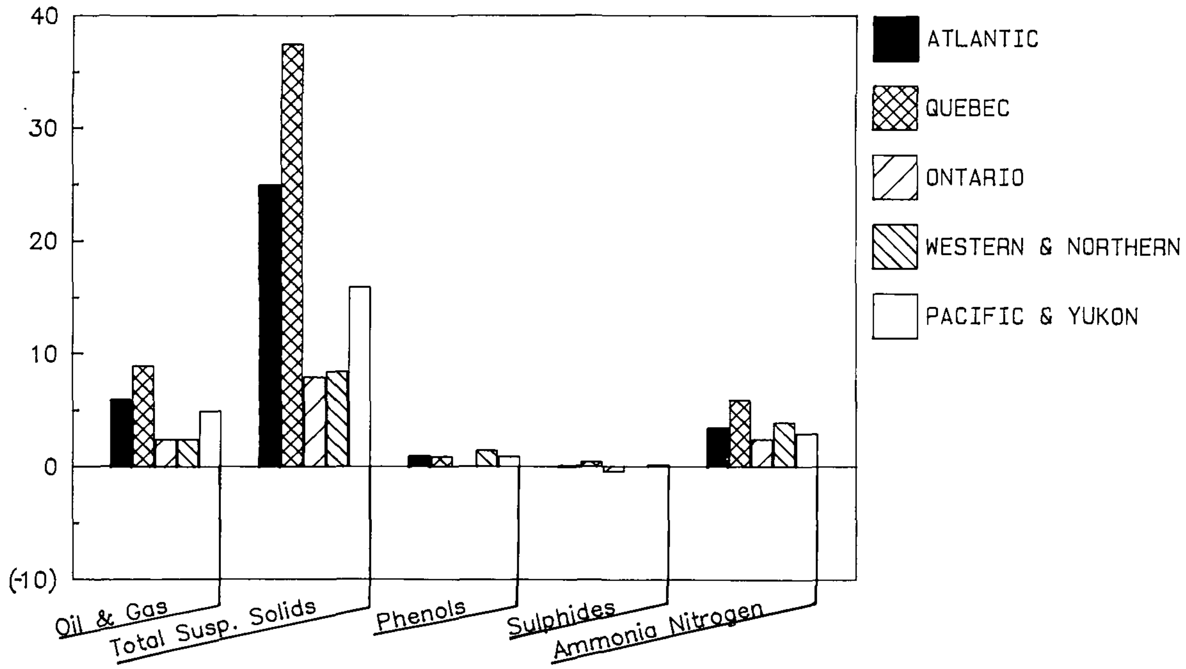


FIGURE 8 COMPARISON OF REGIONAL DEPOSITS OF THE REGULATED PARAMETERS (1987)

Regional Comparison of 1987 Annual Deposits. The 1987 annual average of the deposits in each region is presented in Figure 8. The scale has been magnified for phenols and sulphide in Figures 9 and 10, respectively. All the annual deposits were below the authorized levels. The Quebec region had the highest discharges of oil and grease and total suspended solids; Ontario and Western & Northern regions had the lowest oil and grease discharge and, Ontario had the lowest total suspended solids discharge. The deposits of phenols, sulphide and ammonia nitrogen are comparable in each region, although Ontario had the lowest discharges for all three and a negative net value for sulphide.

Performance of Refineries Subject to Regulations. In 1987, the five new refineries that were assessed complied with the monthly amounts 99% of the time; with the two daily limits more than 99% of the time; and with the stormwater limits 100% of the time. A regional breakdown of compliance with the monthly amounts of the regulations by parameter is provided in Table 10. The low performances were for total suspended solids and sulphide. The refinery responsible for these large deposits of suspended solids and sulphide was Newfoundland Energy Ltd. in Come-by Chance. The refinery started operation in June 1987 and these violations can be attributed to difficulties in bringing the process units on stream. The refinery should improve its performance in the following year. In 1987, 67% of the violations that exceeded the monthly amounts were less than 24% above the limits, the rest were between 100 and 200% above the limits.

Of all the annual deposits from the new refineries in 1987, only Newfoundland's sulphide discharge was above the authorized level. On average, 65% of the tests that are

TABLE 10 PERCENT COMPLIANCE OF REFINERIES IN EACH REGION WITH MONTHLY AVERAGE LIMITS AS SET IN THE REGULATIONS (1987)

	% of Time in Compliance with the Regulations					
Region*	Oil and Grease	Total Suspended Solids	Phenols	Sulphide	Ammonia Nitrogen	Total
Atlantic	100	50	100	0	100	70
Ontario	100	100	100	100	100	100
Western & Northern	100	100	100	100	100	100
Canada	100	98	100	92	100	99

* There are no refineries subject to the regulations in the other regions

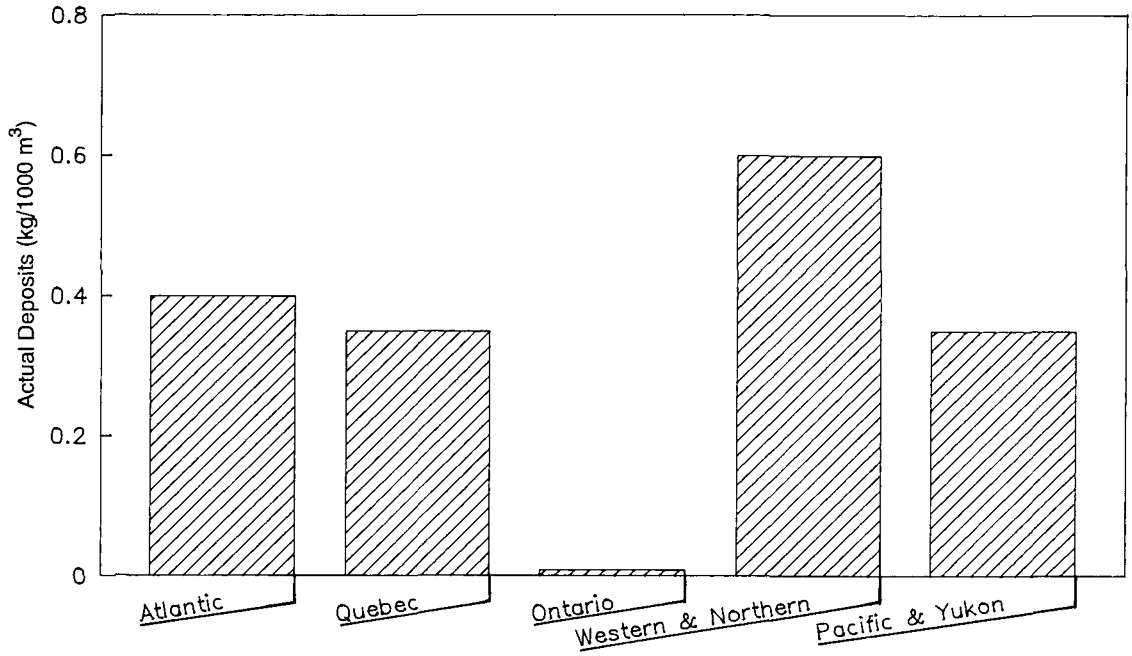


FIGURE 9 COMPARISON OF REGIONAL PHENOL DISCHARGE LEVELS (1987)

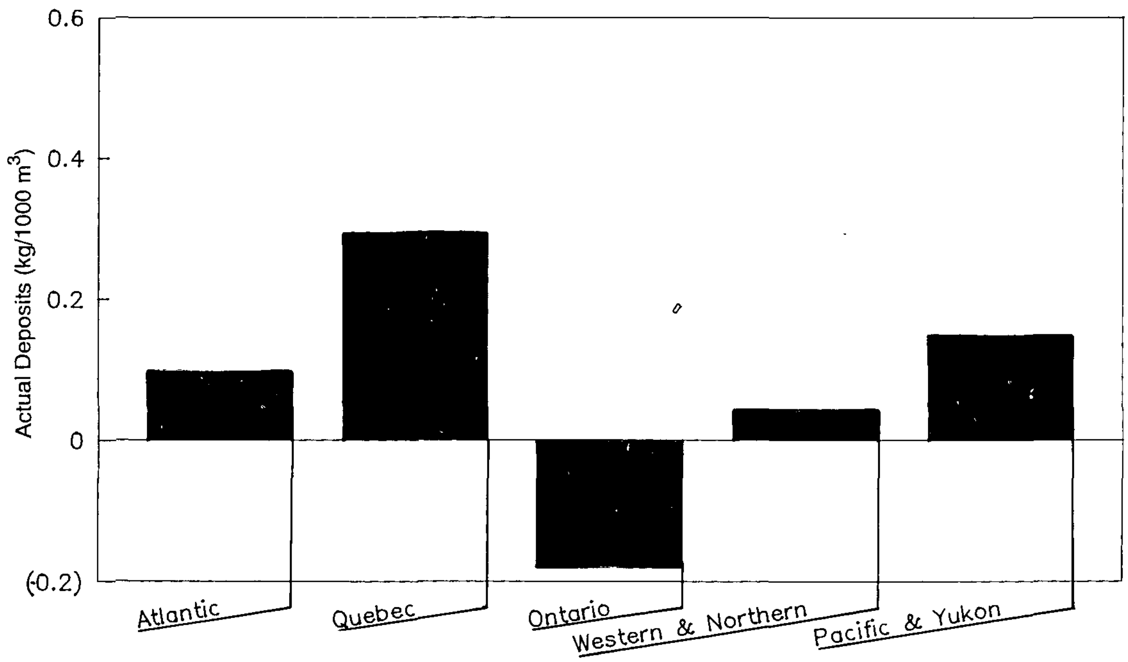


FIGURE 10 COMPARISON OF REGIONAL SULPHIDE DISCHARGE LEVELS (1987)

required by the regulations were reported in 1987. Three refineries were responsible for this low national average: Shell -- Scotford reported only 20% of the tests required, Esso -- Edmonton reported 54% and Newfoundland Energy Ltd., 68%.

Net Discharges 1987. Although the federal regulations and guidelines limit the deposits of several contaminants on a production basis, it would be useful to evaluate the net deposits (in kg/d) to have a better appreciation of the quantity discharged to the environment by the petroleum refining industry. Table 11 provides the total net loadings discharged in 1987 to the various receiving waters. The St. Lawrence River received by far the highest net load of contaminants compared to other receiving waters. This is partly due to the large number of refineries that discharged into it.

TABLE 11 NET LOADINGS TO EACH RECEIVING WATER BODY (1987)

	Net Loadings (kg/d)*				
Receiving Water	Oil and Grease	Total Suspended Solids	Phenols	Sulphide	Ammonia Nitrogen
Halifax Harbour, Dartmouth, N.S	81	428	10	0	34
Little River, St. John, N.B.	146	419	3	2	70
Placentia Bay, Come-by Chance, Nfld.	31	213	1	2	54
St. Lawrence River, Montreal, Que.	398	1596	14	12	205
St. Clair River, Sarnia, Ont.	119	372	0.8	-16	60
Lake Ontario, Mississauga, Ont.	54	253	0.3	3	45
Lake Erie, Nanticoke, Ont.	7	-30	0	-0.02	0.5
North Saskatchewan River, Edmonton, Alta.	88	281	0.4	0.6	10
MacKenzie River, Norman Wells, NWT	14	61	0.06	0.08	1
Red Deer River, Bowden, Alta.**	0	0	0	0	0
McDonald Lake, Balzac, Alta.***	0.2	7	0.03	-	-
Burrard Inlet, B.C.	61	209	2	0.2	25
Peace River, Taylor, B.C.	3	65	0.3	0.8	1
Off-site Treatment****	108	400	39	2	217

* Net loadings represent annual average; ** no effluent was discharged in 1987; *** stormwater discharges only; **** off-site Treatment includes: municipal sewers in Moose Jaw, Regina, Greater Vancouver Regional District, and the Prince George Pulp and Paper Company.

The national net discharges of the regulated parameters from 1972 to 1987 are presented in Table 12. As shown, there has been a general downward trend. Since 1972, the discharge levels of all parameters have been reduced, ranging from 81% for total suspended solids to 99.5% for sulphide. If the 1987 levels are compared to the 1983 levels, reductions ranging from 21% for phenols to 67% for sulphide are found.

TABLE 12 SUMMARY OF TOTAL NATIONAL NET DISCHARGES - REGULATED PARAMETERS

	Discharges (kg/d)						% Reduction since*	
Parameter	1972	1975	1977	1980	1983	1987	1972	1983
Oil and Grease	8 300	9 000	6 000	2 980	1 923	1 080	87	44
Total Suspended Solids	20 900	15 900	15 900	7 175	5 154	4 039	81	22
Phenols	1 800	900	900	200	97	77	96	21
Sulphide	4 600	3 400	900	50	63 **	21 **	99.5	67
Ammonia Nitrogen	10 900	6 700	3 500	1 533	1 205	726	93	40
Reference Crude Rate (10^3 m^3/d)	270	320	320	320	256	248	8	3

* compared to 1987 data.
** Ontario's negative value is not included.

Table 13 presents a regional breakdown of the net discharge levels by contaminant and of the production levels for 1987. If the percent contribution to the national loading is compared with the percent contribution to national production, it is found that: the Atlantic and Quebec regions have a higher loading contribution than production for all parameters; Ontario has a lower loading contribution than production for all parameters; the Western & Northern region has a higher loading contribution for phenols and ammonia nitrogen; and the Pacific & Yukon region has almost the same loading contribution and production for all parameters. As shown in Table 14, the Atlantic region reported an increase in the net discharges for all parameters except ammonia nitrogen from the 1983 levels. A production increase of 51% is mostly responsible for the higher net discharges in this region. The Quebec region decreased its net discharges for most parameters except sulphide. The Ontario region decreased its net discharges for all parameters; sulphide was not compared because for both years the net value was negative. The decreases for both Ontario and Quebec are much higher than the decrease in production which, in general, reflects better regional performance from 1983

TABLE 13 NATIONAL PERCENT PRODUCTION AND DEPOSITS (1987)

	Percent of National				
	Atlantic Region	Quebec Region	Ontario Region	Western & Northern Region	Pacific & Yukon Region
Production (%)	16.5	17.7	31.2	25.1	9.5
Deposits (%)					
Oil and Grease	24.6	37.0	15.8	12.9	9.7
Suspended Solids	24.9	39.5	14.2	12.2	9.2
Phenols	21.2	18.9	1.0	48.7	10.2
Sulphide	19.6	59.0	0	9.0	12.4
Ammonia Nitrogen	17.4	28.2	14.9	31.7	7.8

TABLE 14 PERCENT REDUCTION OF NET DEPOSITS AND OF PRODUCTION BETWEEN 1983 and 1987

	% Reduction by Region					
	Atlantic	Quebec	Ontario	Western & Northern	Pacific & Yukon	Canada
Reference Crude Rate	-51	32	8	-11	7	3
Oil and Grease	-7	65	42	-12	-0.2	44
Total Suspended Solids	-34	39	43	10	-36	22
Phenols	-55	64	82	-51	54	21
Sulphide	-372 *	-47	**	96	35	67
Ammonia Nitrogen	22	54	32	37	21	40

* mostly Newfoundland Energy Ltd.

** negative net value in 1983 and 1987

to 1987. The Western & Northern region decreased most of its net discharges even though production increased by 11%. However, net discharges of oil and grease, and phenols increased. For oil and grease, the increase in net discharge is similar to the increase in production. For phenols, this should be a credit to the low level achieved in 1983 rather than a deterioration of regional performance. The Pacific & Yukon region has decreased most of its net discharges. Oil and grease stayed at the same level. However there was a big increase in the total suspended solids level. Again, this increase is not necessarily a reflection of regional performance. Despite these increases, all 1987 net deposits in each region remained below the authorized levels.

3.4.2 Atlantic Region Assessment. Three refineries in the Atlantic region have an "existing" status and are subject to the guidelines. In addition, the region has one new refinery, Newfoundland Energy Ltd. which originally came on line in December, 1973, and must then comply with the more stringent regulation limits. The refinery was shut down for 11 years from March 1976 and restarted operations in June 1987. The individual performance of the refineries in this region for 1987 are presented in Appendix B.

In 1987, the region was in compliance with the monthly amounts more than 96% of the time. Texaco and Irving were in full compliance with all the monthly limits; Esso was in compliance with the monthly amounts 95% of the time and Come-by Chance, 70% of the time. The overall performance of each refinery is provided in Table 9. As shown in Table B-2 (Appendix B), half of the deposits that exceeded the monthly amounts were less than 25% above the limits, and all except one were less than 100% above the limits. The one-day amounts and maximum daily amounts were exceeded very few times (in compliance more than 99% of the time). All the limits for oil and grease were always met; pH was within the limit more than 99% of the time; toxicity met the limit 89% of the time, ammonia nitrogen was in full compliance with the monthly amount and the one-day amount; and the other three parameters were in compliance with the monthly amounts at least 87% of the time.

The percentage of time the region was in compliance with the monthly amounts went from 96% in 1983 to 94% in 1984 and back to 96% in 1987. The situation in 1987 is equivalent to 1983.

The annual regional deposits between 1972 to 1987 are presented for each parameter in Figures 11 to 15. The performance in 1987 improved from 1983. Three parameters experienced reductions of 11 to 48%. Phenol deposits stayed at the same level. Sulphide deposits more than tripled, however, it is important to stress that all the actual deposits since 1980 were far below the authorized levels so perhaps these statistics

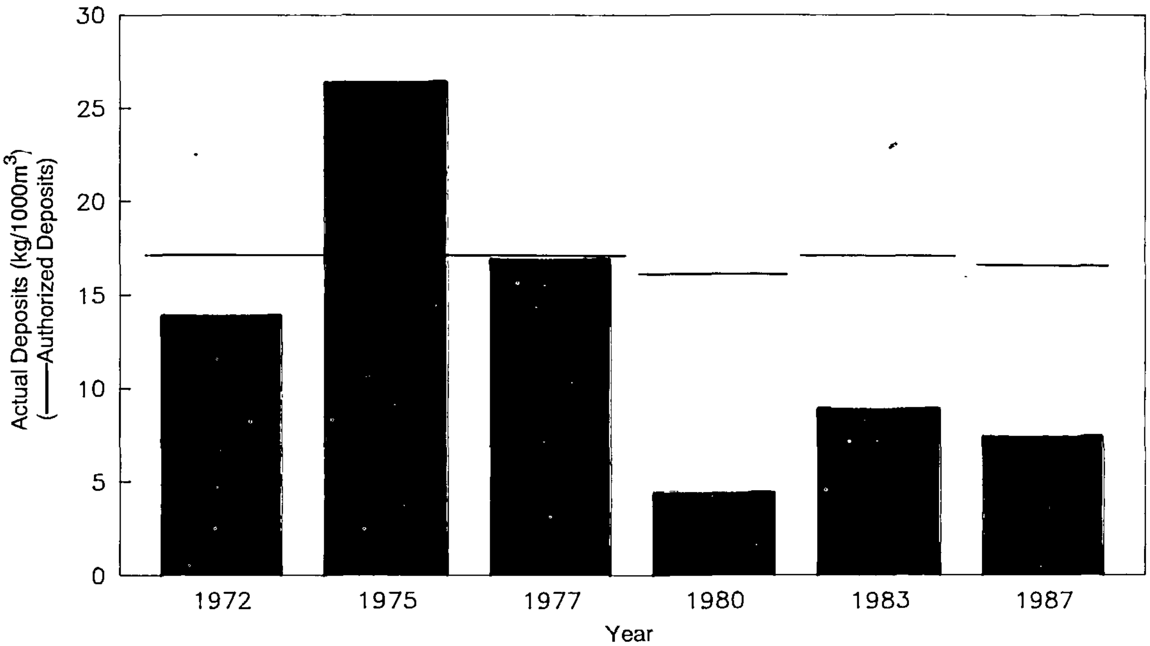


FIGURE 11 AVERAGE OF ANNUAL DISCHARGES OF OIL AND GREASE (Atlantic Region - 1972 to 1987)

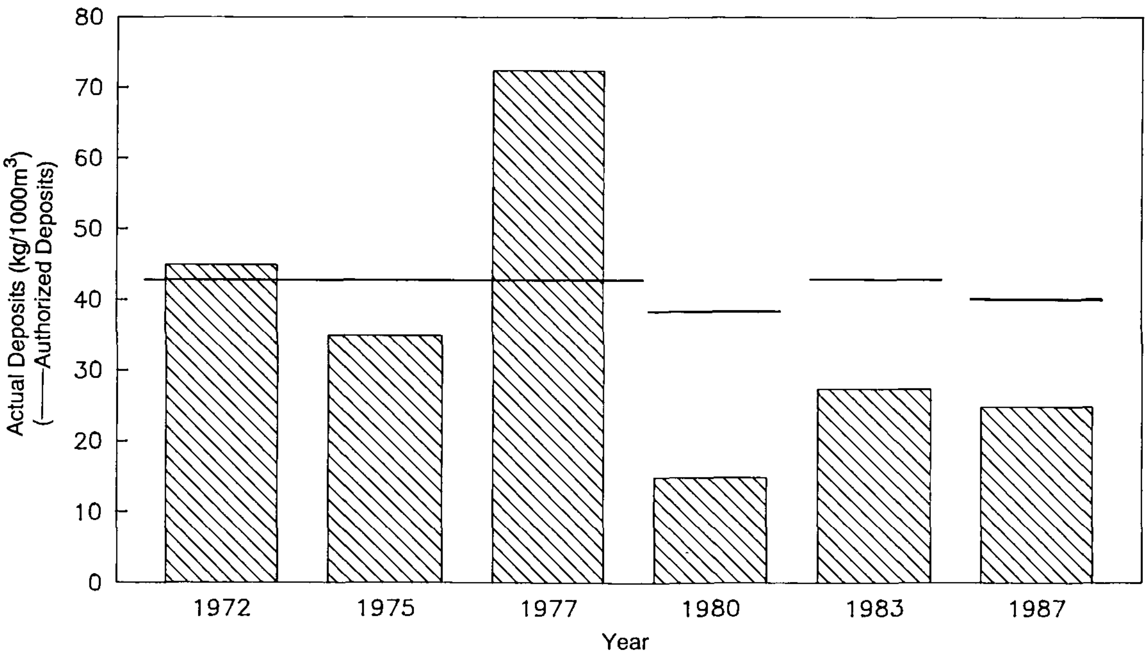


FIGURE 12 AVERAGE ANNUAL DISCHARGES OF TOTAL SUSPENDED SOLIDS (Atlantic Region - 1972 to 1987)

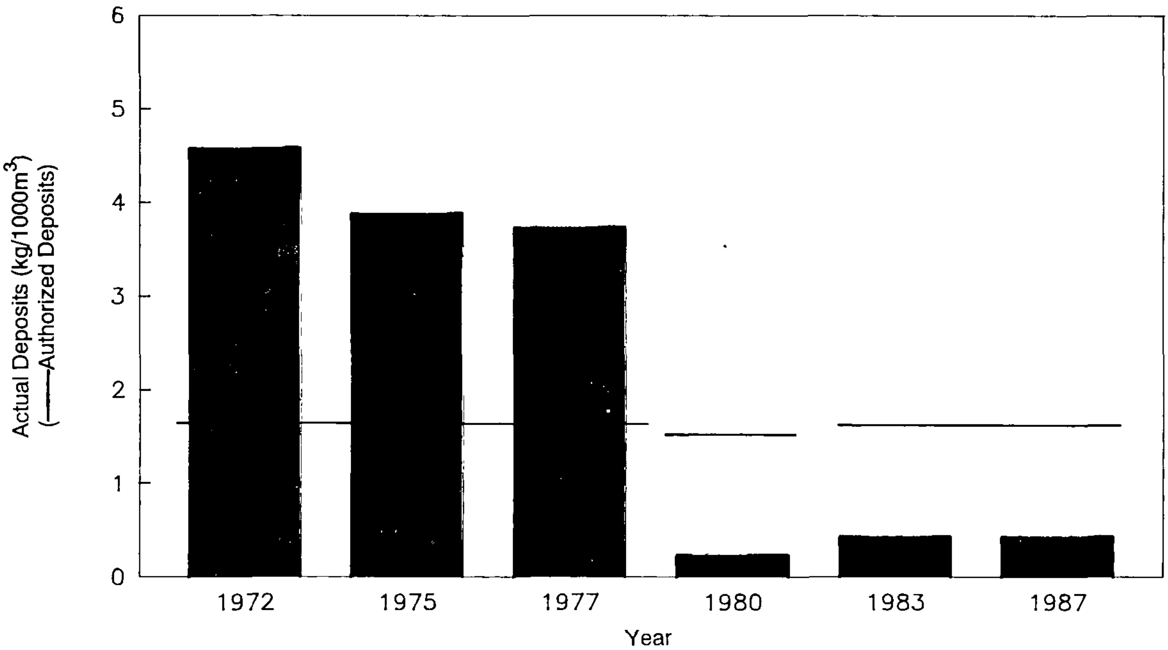


FIGURE 13 AVERAGE ANNUAL DISCHARGES OF PHENOLS (Atlantic Region - 1972 to 1987)

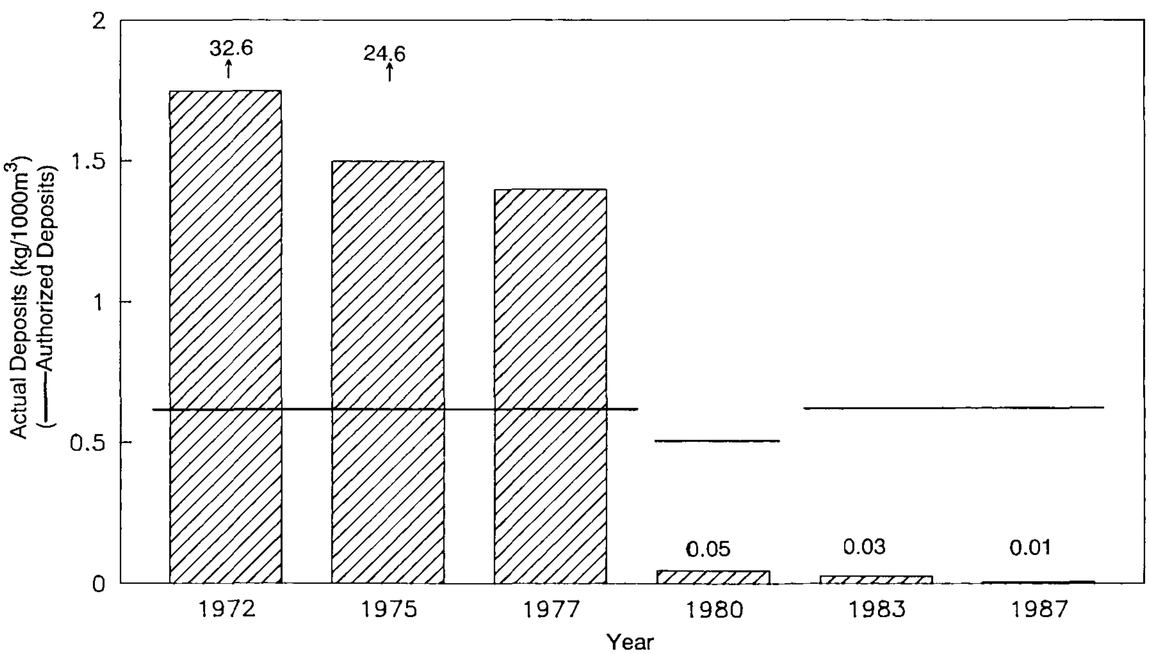


FIGURE 14 AVERAGE ANNUAL DISCHARGES OF SULPHIDE (Atlantic Region - 1972 to 1987

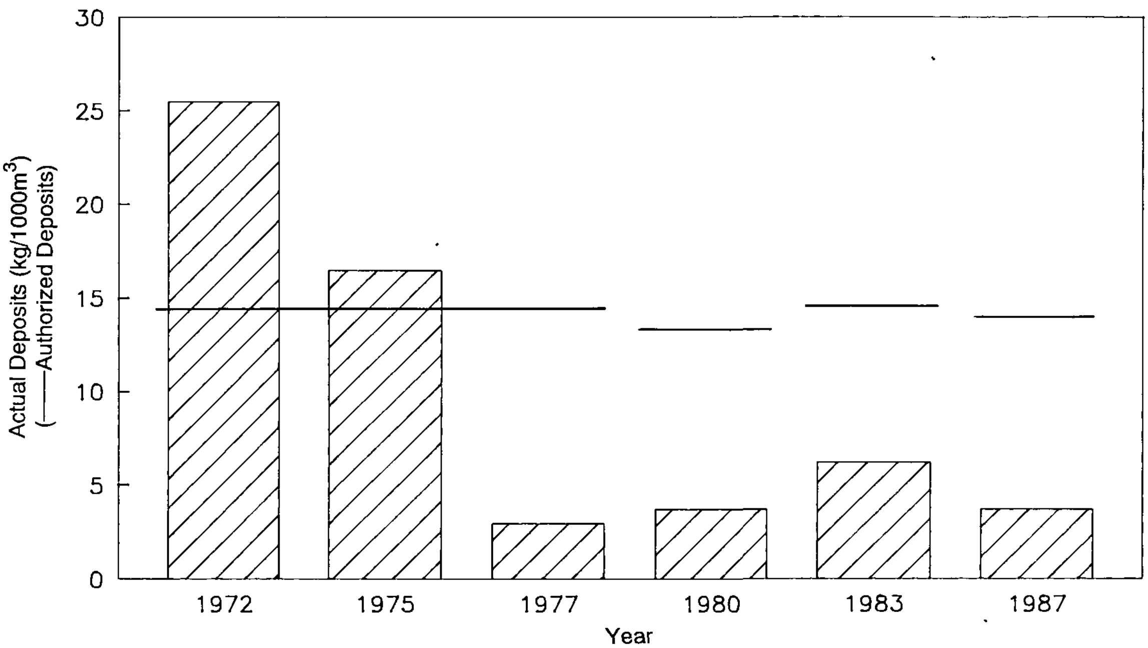


FIGURE 15 AVERAGE ANNUAL DISCHARGES OF AMMONIA NITROGEN (Atlantic Region - 1972 to 1987)

are more a credit to the region's achievement during the 1980's than a criticism of its 1987 performance.

A comparison of the average deposits from each refinery in 1987 is provided for all the parameters in Figures 16 to 20. The discharges of all refineries were below the authorized/guideline deposits. Esso--Dartmouth had the highest discharge of total suspended solids and phenols and the lowest sulphide discharge; Irving--St. John had the highest oil and grease discharge; Texaco--Dartmouth had the best performance overall; and Come-by Chance had highest ammonia and sulphides discharge and the lowest phenols discharge.

Of all the requested tests in the region, 3% were not reported in 1987. The production was increased by 50%, compared to 1983 level. This increase was not only due to Come-by Chance coming back on line, but also an increase in production at the other three refineries. The performance of each refinery in this region is presented in Table 15 giving the 1987 values for each parameter.

Esso Petroleum--Dartmouth, N.S. Esso has a secondary treatment system (activated sludge) and discharges its treated effluent into Halifax harbour.

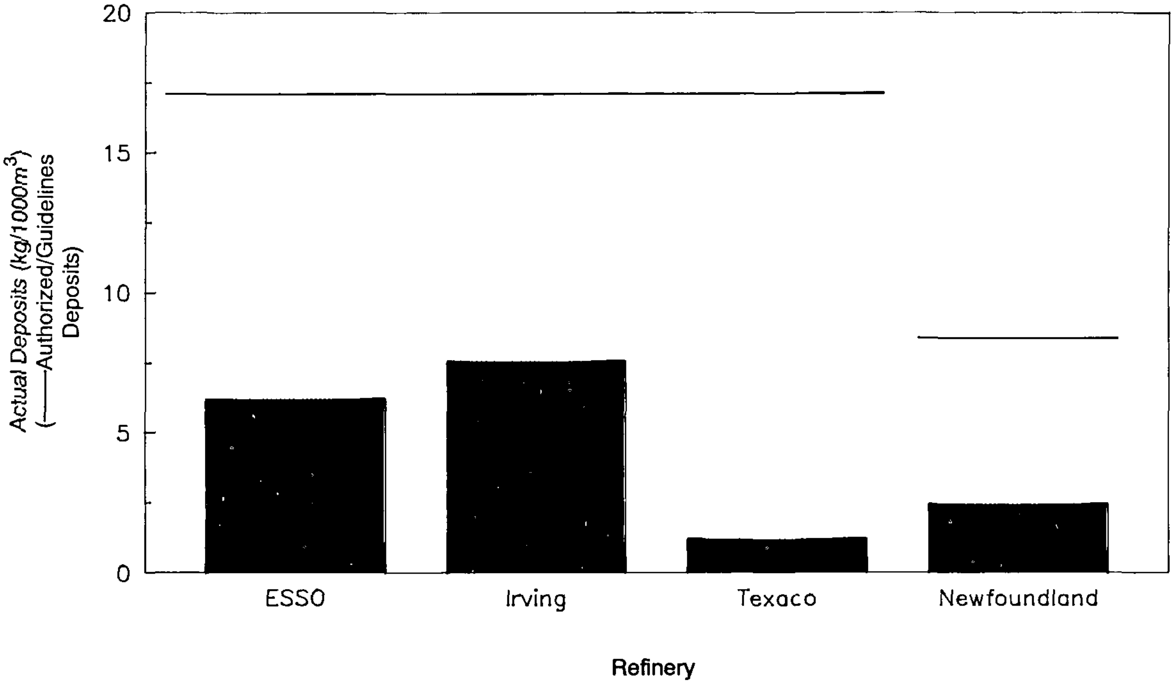


FIGURE 16 OIL AND GREASE DISCHARGE LEVELS BY REFINERY (Atlantic Region - 1987)

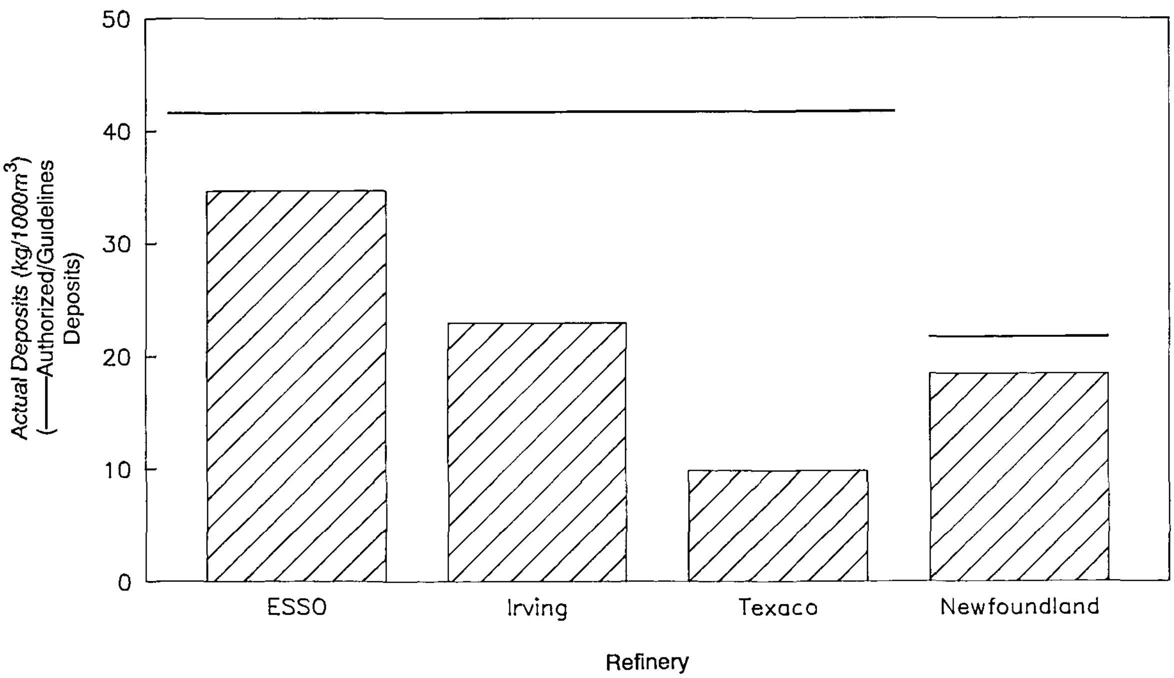


FIGURE 17 TOTAL SUSPENDED SOLIDS DISCHARGE LEVELS BY REFINERY (Atlantic Region - 1987)

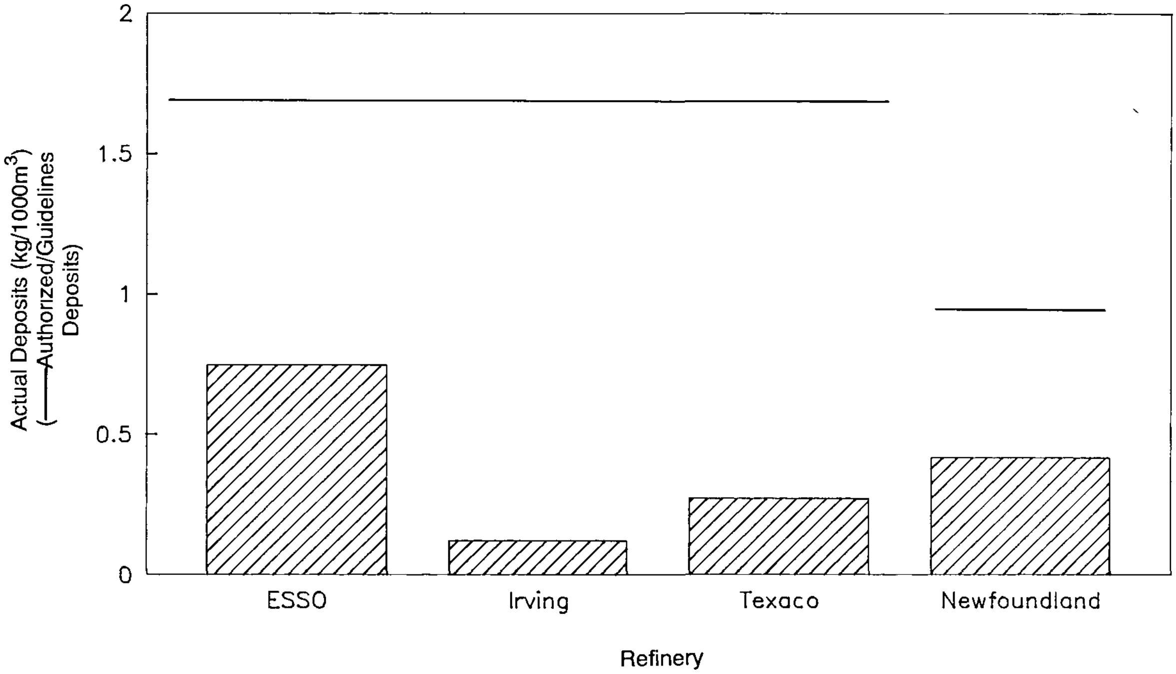


FIGURE 18 PHENOLS DISCHARGE LEVELS BY REFINERY (Atlantic Region - 1987)

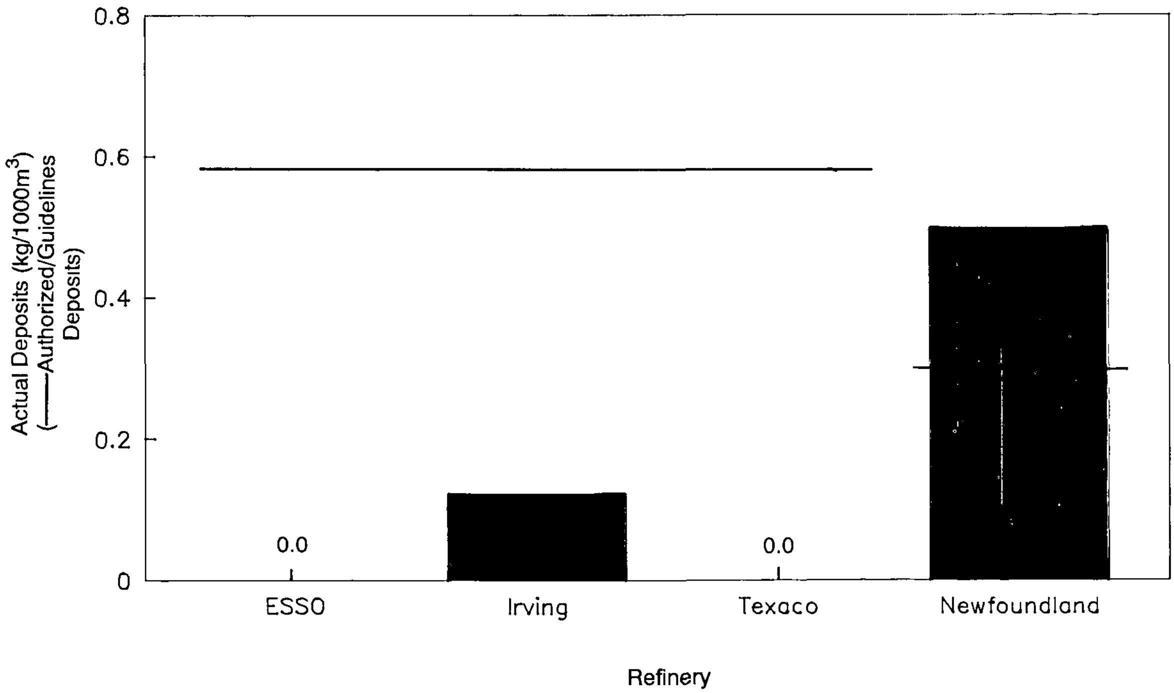


FIGURE 19 SULPHIDE DISCHARGE LEVELS BY REFINERY (Atlantic Region - 1987)

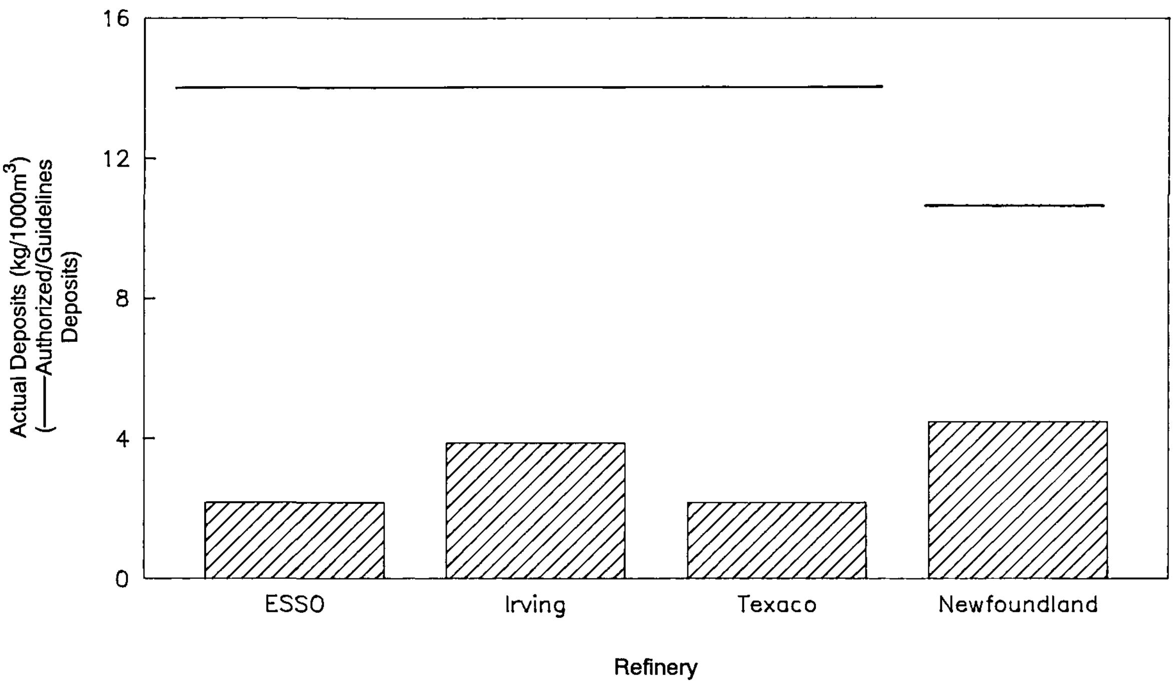


FIGURE 20 AMMONIA NITROGEN DISCHARGE LEVELS BY REFINERY (Atlantic Region - 1987)

TABLE 15 REFINERY FREQUENCY OF NON-COMPLIANCE WITH THE REGULATED PARAMETERS (Atlantic Region - 1987)

	% of time not in compliance																
	Oil and Grease			Total Suspended Solids			Phenols			Sulphide			Ammonia Nitrogen			pH	Toxicity
Refinery	M	O	N	M	O	N	M	O	N	M	O	N	M	O	N	N	N
Esso Petroleum (Dartmouth)	0	0	0	16.6	0	4.5	8.3	0.6	3.2	0	0	0	0	0	0	0	8.3
Irving (St. John)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25
Texaco (Dartmouth)	0	0	0	0	0	1.6	0	0	0	0	0	0	0	0	0	0.3	0
Newfoundland Energy Ltd. (Come-by Chance)	0	0	0	50	12.8	15.4	0	0	0	100	15.8	2.6	0	0	2.6	NR	NR

M : monthly amount; O : one-day amount; N : maximum daily amount; NR : not reported

In 1987, Esso was in compliance with the federal guidelines for oil and grease, sulphide and ammonia nitrogen. Numerous deposits of total suspended solids and phenols exceeded the guideline levels.

Esso was in compliance with the monthly amounts 95% of the time and more than 99% of the time for the daily limits. One deposit that exceeded the monthly amounts was less than 25% above the limit and the other two deposits were beween 50 and 100% above the limit. The annual average deposits for 1987 were all below the guideline limits. All of the tests requested were reported.

Esso's performance improved from that of 1983; the number of excursions for oil and grease, total suspended solids, phenols and pH has decreased.

Irving--St. John, N.B. Irving, the largest refinery in the Atlantic region, has a secondary treatment system consisting of an activated sludge process. The treated effluent is discharged into the Little River (which flows into St. John harbour).

Irving was within the allowable limits of the guidelines in 1987 for oil and grease, total suspended solids, phenols, sulphide, ammonia nitrogen and pH. There were, however, three toxicity test failures.

In general, Irving performed very well during 1987 with full compliance with the monthly and one-day amounts, and in compliance more than 99% of the time with the maximum amount. The annual average deposits were all below the limits. All the tests required under the guidelines were reported except one.

In 1987, Irving had a better performance than 1983. The refinery showed a reduction of oil and grease, total suspended solids and ammonia deposits. Phenols and sulphides deposits have increased, but the levels of deposits were still far below guideline levels.

Texaco—Dartmouth, Nova Scotia. Texaco treats its effluent with an activated sludge biological system and then discharges it into Halifax harbour (Eastern Passage).

The company operates under the guidelines and had an excellent performance in 1987. There was full compliance with the monthly and one-day amounts and more than 99.9% of the time in compliance with the maximum amounts. There were two excursions for total suspended solids and one with pH in 1987, as opposed to no excursions in 1983.

Only 95% of the requested tests were reported and all the deposits were below guideline levels.

Newfoundland Energy Ltd.—Come-by Chance, Nfld. The Come-by Chance refinery originally started to operate in December 1973, and was subject to the federal regulations. In March 1976, the refinery was shut down but restarted operating 11 years. Operations were resumed in June 1987. However, there were several fires at the plant from June to December 1987, and it was forced to shut down on several occasions; it began discharging in November 1987. The refinery has a secondary treatment system (activated sludge) and discharges the treated effluent to Placentia Bay.

Come-by Chance was in compliance with the monthly amounts 70% of the time, 94% with the one-day amount and 96% with the maximum daily amount. Violations occurred mainly for total suspended solids and sulphides. There was one violation to the maximum daily amount for ammonia nitrogen. Two out of three monthly amount violations were less than 25% above the limit and all were less than 200% above the limit. The refinery reported 68% of the required test, none of the pH and toxicity tests required were reported. The annual average deposits were all below the authorized levels with the exception of sulphide. Most of the violations can be attributed to bringing the process on stream. In the following year performance should improve and all the required tests be reported.

3.4.3 Quebec Region Assessment. In 1987, three refineries were operating in Quebec. All have an "existing" status and are subject to the guidelines. Shell and Petro-Canada treated a combined effluent generated by the refinery and by an adjacent petrochemical plant. The 1987 individual refinery performance is shown in Appendix B.

In some cases, excessive allowable deposits were given to refineries. This occurred when the refineries did not declare a revised reference crude rate when their average stream day crude rate (sustained for two consecutive months) was less than 85% of the last declared RCR. The refineries should, in the future, declare a revised RCR when appropriate.

The 1987 performance was 91% of the time in compliance with the monthly amounts. Shell had the lowest percentage with 83% of the time in compliance. Petro-Canada and Ultramar were in compliance 93% and 97% of the time respectively. As shown in Table B-3 (Appendix B), 75% of the deposits that exceeded the monthly amounts were less than 50% above the limit and almost all of them were less than 200% above the limit. The one-day amount and maximum daily amount were each in compliance more than 98% of the time. The standards that were exceeded most often were total suspended solids (exceeded 22% of the time for the monthly amounts, mostly by Shell) and oil and grease (8% of the time). Phenols, sulphide, ammonia nitrogen and pH were also exceeded occasionally.

The overall regional performance has improved since 1983. The percentage of time the region was in compliance with the monthly amounts increased from 79% in 1983 to 91% in 1987.

A trend analysis of the annual regional deposits between 1972 and 1987 is illustrated in Figures 21 to 25. In 1987 the region's performance improved over the 1983 level, with decreases in deposits of four parameters (oil and grease, total suspended solids, phenols and ammonia nitrogen). The level of deposits for sulphide has increased by 115%. Nevertheless, general performance has improved and the deposits of all parameters were noticeably below the limits.

The 1987 discharge levels for each refinery in the region are presented in Figures 26 to 30. The discharges from all refineries were below the limits for oil and grease, phenols and ammonia nitrogen. The highest discharge of oil and grease was from Petro-Canada and the lowest was from Ultramar; for total suspended solids, Shell had the highest discharge and Ultramar had the lowest; for phenols, Petro-Canada had the highest discharge and Shell had the lowest; for sulphide, Ultramar had the highest discharge and Petro-Canada had the lowest; and for ammonia nitrogen, Petro-Canada had the highest and Ultramar had the lowest. The guideline level for total suspended solids was exceeded by one refinery -- Shell. For sulphide, the guideline level was slightly exceeded by Ultramar.

More than 98% of all requested tests in the region were reported. The production in 1987 was 32% lower than the 1983 level. These reductions were mainly caused by refinery closures. The performance of each refinery in this region is presented in Table 16 giving the 1987 value for each parameter.

Petro-Canada--Pointe-aux-Trembles. This Petro-Canada refinery has a secondary treatment system consisting of bio-filters and a polishing pond. The combined treated effluent (from the refinery and adjacent petrochemical plant) is discharged into the St. Lawrence River.

Petro-Canada is subject to the guidelines. In 1987, the refinery experienced problems primarily with ammonia nitrogen, but excessive deposits were also reported for oil and grease as well as one toxicity test failure. The other parameters (total suspended solids, phenols, sulphide and pH) were in full compliance. The monthly amounts for oil and grease, and ammonia nitrogen were each exceeded two times out of 12. The one-day amounts were also exceeded for both parameters and the maximum daily amount was exceeded for ammonia nitrogen. These large deposits of ammonia nitrogen were due to

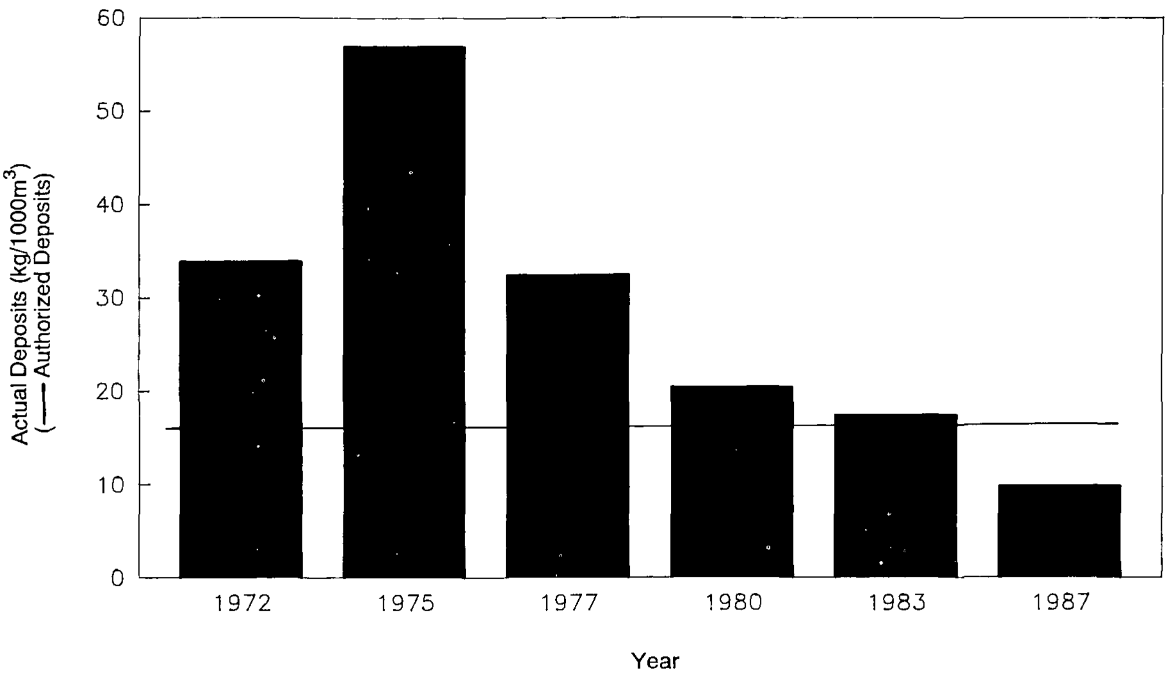


FIGURE 21 AVERAGE ANNUAL DISCHARGES OF OIL AND GREASE (Quebec Region - 1972 to 1987)

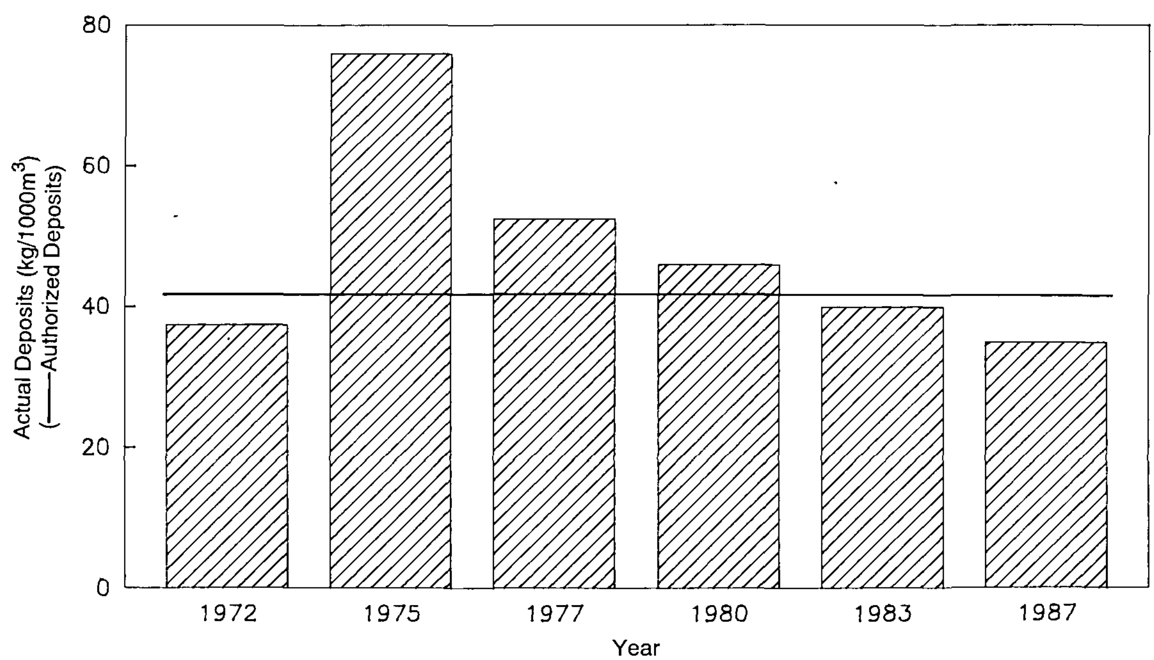


FIGURE 22 AVERAGE ANNUAL DISCHARGES OF TOTAL SUSPENDED SOLIDS (Quebec Region - 1972 to 1987)

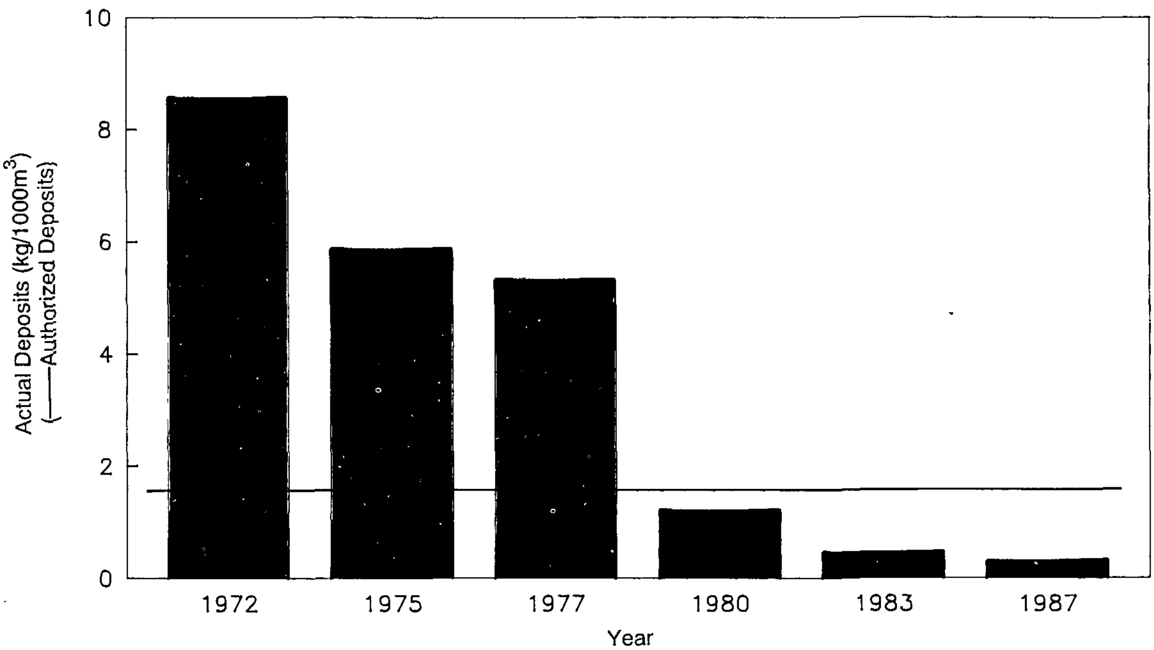


FIGURE 23 AVERAGE ANNUAL DISCHARGES OF PHENOLS (Quebec Region - 1972 to 1987)

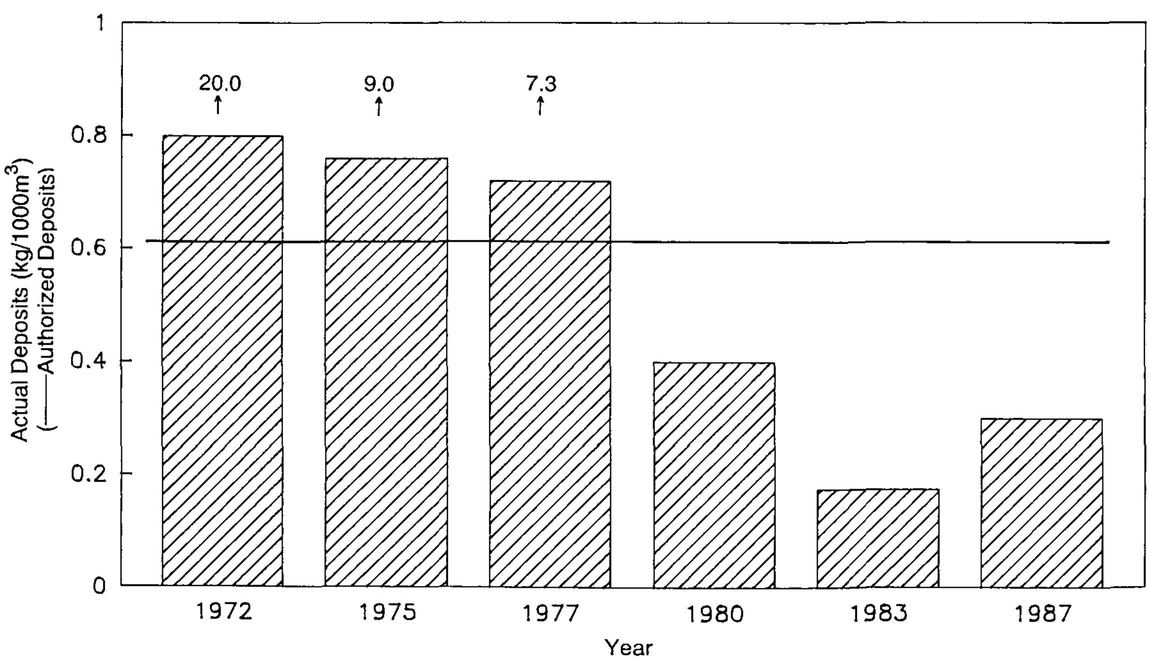


FIGURE 24 AVERAGE ANNUAL DISCHARGES OF SULPHIDE (Quebec Region - 1972 - 1987)

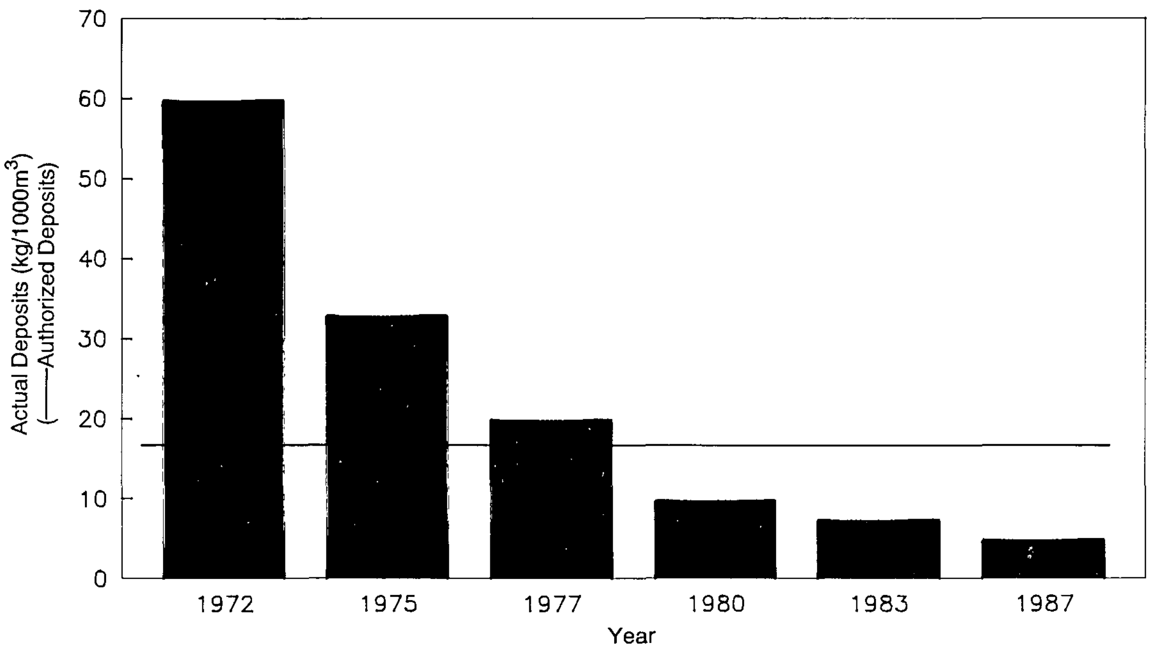


FIGURE 25 AVERAGE ANNUAL DISCHARGES OF AMMONIA NITROGEN (Quebec Region - 1972 to 1987)

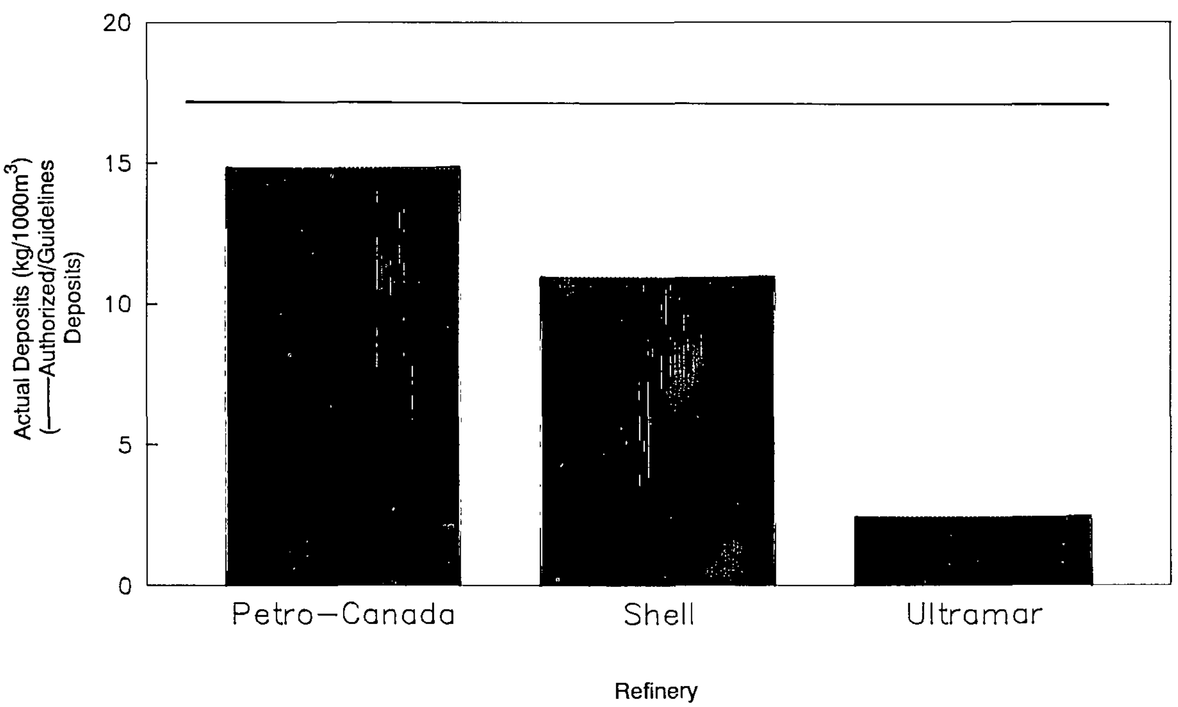


FIGURE 26 OIL AND GREASE DISCHARGE LEVELS BY REFINERY (Quebec Region - 1987)

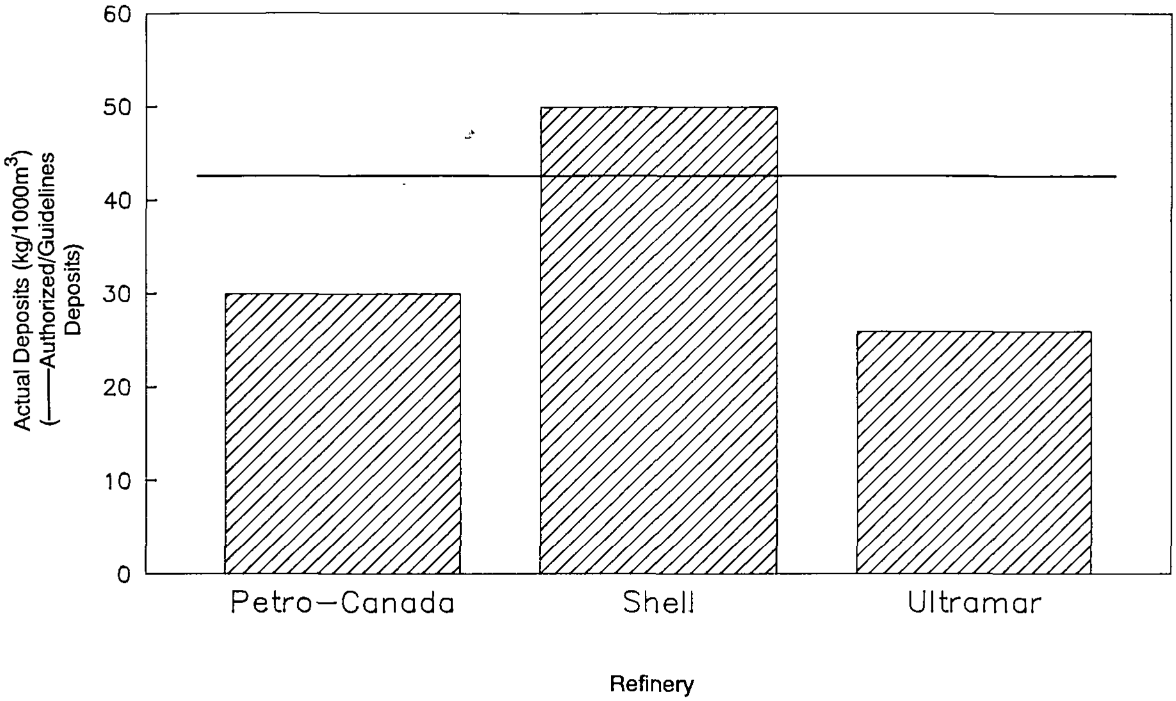


FIGURE 27 TOTAL SUSPENDED SOLIDS DISCHARGE LEVELS BY REFINERY (Quebec Region - 1987)

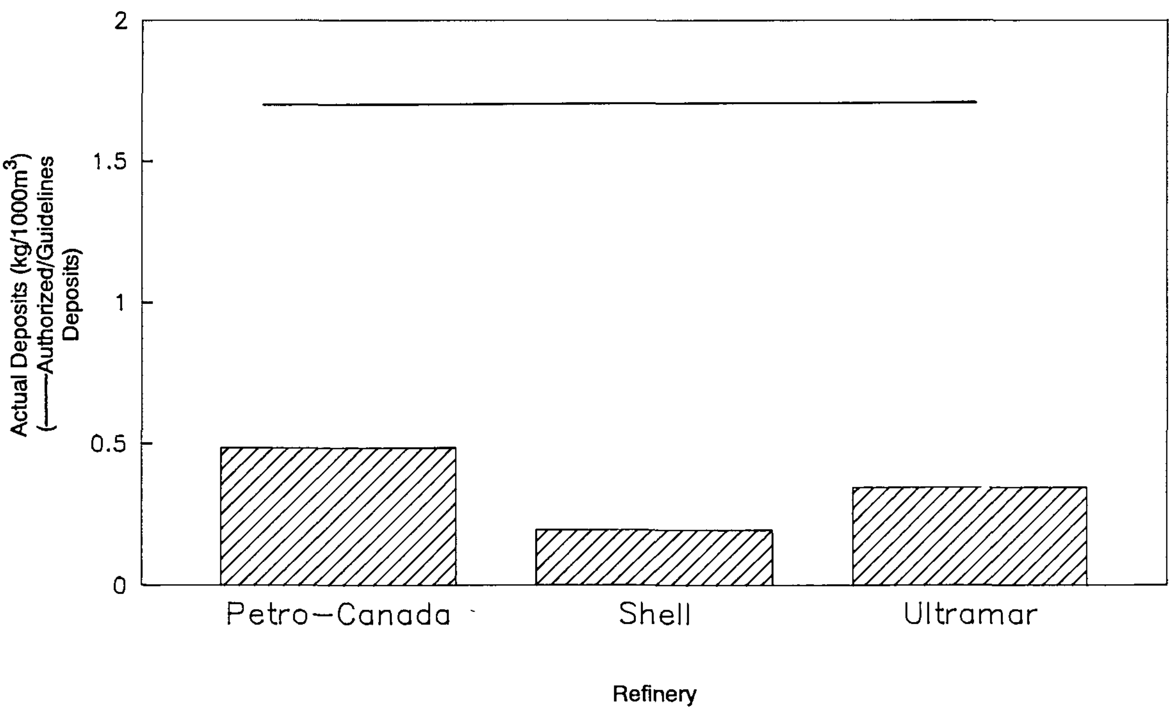


FIGURE 28 PHENOLS DISCHARGE LEVELS BY REFINERY (Quebec Region - 1987)

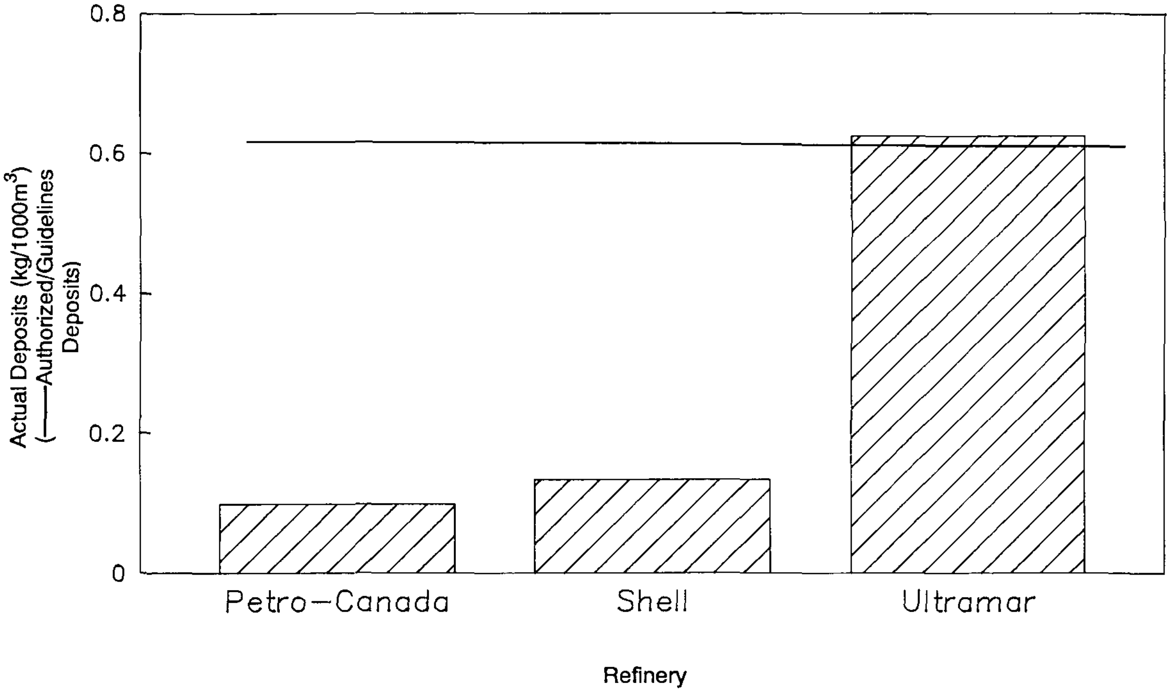


FIGURE 29 SULPHIDE DISCHARGE LEVELS BY REFINERY (Quebec Region - 1987)

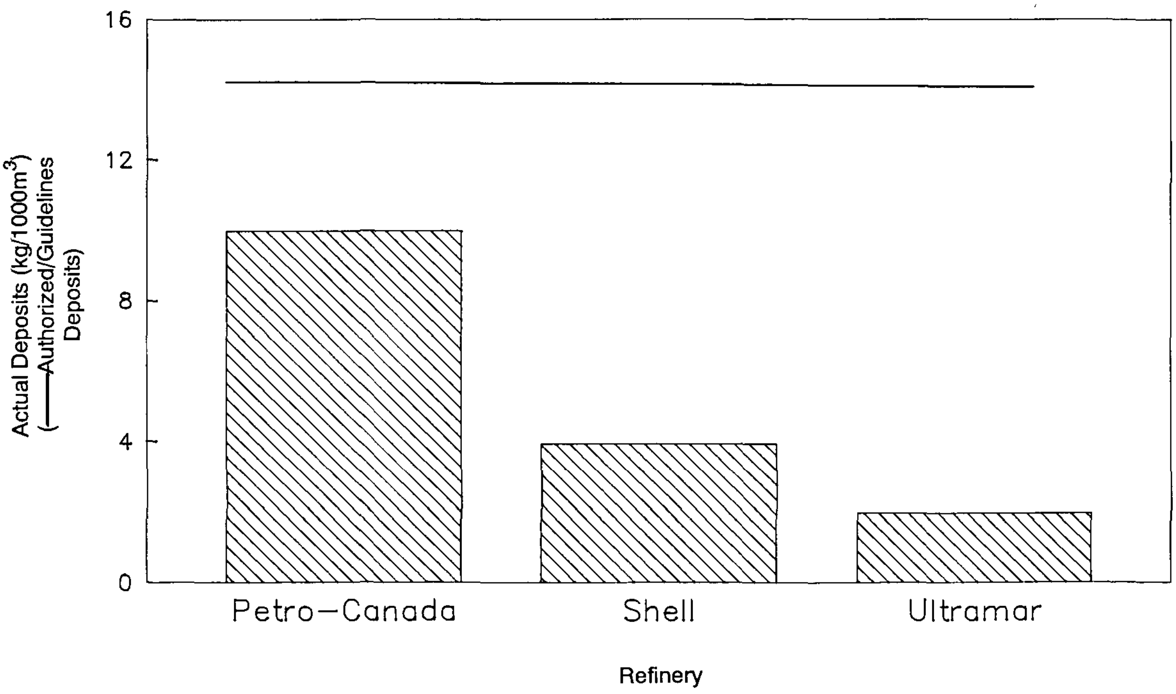


FIGURE 30 AMMONIA NITROGEN DISCHARGE LEVELS BY REFINERY (Quebec Region - 1987)

TABLE 16 REFINERY FREQUENCY OF NON-COMPLIANCE WITH THE REGULATED PARAMETERS (Quebec Region - 1987)

	% of time not in compliance																
	Oil and Grease			Total Suspended Solids			Phenols			Sulphide			Ammonia Nitrogen			pH	Toxicity
Refinery	M	O	N	M	O	N	M	O	N	M	O	N	M	O	N	N	N
Petro-Canada (Pointe-aux-Trembles)	16.7	2	0	0	0	0	0	0	0	0	0	0	16.7	7.9	7.9	0	8.3
Shell (Montreal)	8.3	0	1.9	66.7	14.8	11	0	0	0.7	8.3	0.7	1.3	0	1.3	2	0.3	0
Ultramar (St-Romuald)	*0*	*0*	*0*	*0*	*0.7*	*2*	*8.3*	*0.7*	*2*	*8.3*	*0*	*0.7*	*0*	*0*	*0*	*2.5*	*0*

M : monthly amount; O : one-day amount; N : maximum daily amount.
NR - not reported.

the gradual formation of solid deposits in the tower of the sour water stripping unit for ammonia removal. When the accumulation of the solid deposits is too high, the efficiency of the stripper unit is reduced. To prevent further reduction of efficiency in the sour water stripper which results in high deposits of ammonia nitrogen, the company now shuts the system down when the accumulation of solid deposits is too high and stores the sour water while the tower is being cleaned. Even though there were some excursions for oil and grease, there has been great improvement since 1983. In 1986, the company installed a permanent system of polyelectrolyte injection in their primary treatment.

The overall performance of Petro-Canada in 1987 was 93% of the time in compliance with the monthly amounts and 98% of the time with the daily limits. Three-quarters of the monthly amounts exceeded the limits by less than 25% and the last quarter was between 100 and 200% above the limit. The annual average deposits of all parameters were below the guideline limits. Most of the 1987 deposits were lower than the 1983 deposits except for ammonia nitrogen which increased by 74%. Petro-Canada reported more than 98% of the requested tests.

Shell--Montreal. The Shell refinery also has petrochemical processes. The combined effluent from the refinery and the chemical plant receives biological treatment (activated sludge) and is discharged into the St. Lawrence River.

Shell operates under the guidelines and was in compliance only for toxicity in 1987. The maximum daily limits were exceeded once for pH and phenols; a significant number of deposits for all the other parameters were above the limits, especially total suspended solids. Shell introduced a polyelectrolyte in the dissolved air flotation unit to aid in the separation of emulsions. As a result, the number of excursions for oil and grease in 1987 decreased by more than 70% compared to 1983. Total suspended solids discharges were the refinery's primary concern since the monthly amount was exceeded 67% of the time. The problem was caused by the difficulties in removing oil emulsions from the air flotation unit, which affected the biological treatment system. The oil in the effluent prevented the activated sludge from successfully forming large flocs which would allow the sludge to settle out and be recycled. Instead, the sludge was flushed out of the system creating the high level of suspended solids. Although the company has reduced the number of excursions for total suspended solids, it should be noted that the large number of excursions have been an ongoing problem since 1982. All efforts to improve the situation have been fruitless. Greater efforts to solve this problem will have to be made by the company. The refinery also exceeded the limits for phenols, sulphide, and ammonia nitrogen. The exceedances were partly due to spills of sulphuric acid and phenolitic caustic soda, and frequent and chronic clogging up of the acid gas stripper.

The 1987 assessment of Shell was 83% of the time in compliance with the monthly amounts; 97% of the time with the one-day amounts; and 98% of the time with the maximum daily amounts. Eighty percent of the deposits that were in excess of the monthly amounts were less than 50% above the limit and the remaining 20% was between 50% and 100% above the limit. The annual average of the total suspended solid discharges was significantly above the guideline level, and the deposits of the other parameters were below the limit. Shell provided 99% of the requested tests.

Ultramar—St.Romuald. Ultramar is subject to the guidelines. After commissioning a catalytic cracking unit, the refinery upgraded its wastewater treatment system by installing aerated lagoons. The system came on stream in late 1982. The treated effluent is discharged into the St. Lawrence River.

Ultramar reported compliance for oil and grease, ammonia nitrogen and toxicity. The refinery had a very good performance in 1987. The company went from having major problems with oil and grease, and ammonia nitrogen in 1983 to no excursions in 1987. Two monthly amounts excursions were reported for phenols and for sulphides. The effluent also exceeded the one-day limits and/or maximum daily limits for total suspended solids, phenols, sulphide and pH. Excursions were mainly due to minor problems such as the use of used caustic soda as opposed to fresh and the breakdown of the sulphuric acid injection system.

In 1987, Ultramar was in compliance with the monthly amounts 97% of the time, more than 99% of the time with the one-day amounts and 99% with the maximum daily amounts. One monthly amount exceeded the limit by less than 50%, however, the sulphide excursion exceeded the monthly amount by more than 1100%. All of the annual average discharges were well below the guideline deposits, except for sulphide. The annual deposit for sulphide was slightly above the guideline level, largely because of a major exceedance that occurred in the month of February. This was caused by the used caustic soda containing a lot of sulfur thus provoking this increase in sulphide discharge. The company reported 98% of the requested tests.

3.4.4 Ontario Region Assessment. In 1987, seven refineries were operating in Ontario; five were subject to the guidelines with three in the existing category and two is the expanded category. The other two refineries were new and were subject to the regulations. Esso in Sarnia, and Shell and Petrosar in Corunna are associated with petrochemical plants and treat a combined effluent (refinery and petrochemical) in the refinery's treatment system. At the Esso refinery, the affiliated petrochemical plant has its own wastewater treatment system, but some of its effluent is treated by the refinery system. All of the refineries in the region discharge treated effluent into the part of the Great Lakes system which includes the St. Clair River, Lake Ontario and Lake Erie. The individual refinery performance for 1987 is summarized in Appendix B.

In 1987, the refineries were in compliance with the monthly amounts more than 97% of the time. Four refineries, including the new ones, were in compliance with the monthly amounts 100% of the time. The other three: Petro-Canada--Trafalgar, Shell--Corunna, and Suncor--Sarnia were in compliance 98%, 88%, and 97% of the time, respectively. As shown in Table B-4 (Appendix B), 54% of the deposits in excess of the monthly amounts were less than 50% above the limit, and 82% were less than 100% above the limit. The refineries were also in compliance with the two daily limits more than 99% of the time. Phenols, pH and toxicity levels were never exceeded by any refinery. The parameter that was most exceeded was total suspended solids. It was in compliance with the monthly amounts 92% of the time and 99% and 98% for the two daily limits.

For monthly amount limits, the region was in compliance 97% of the time in 1987 from 99% in 1983. However, the number of deposits that exceeded the daily limits was reduced in 1987. The refinery that contributed most to this lower performance was Shell, which was responsible for 70% of the total regional noncompliance for the monthly limits (mostly total suspended solids).

The annual average loadings from 1972 to 1987 are presented in Figures 31 to 35. Actual deposits were lower than 1983 for most parameters; there was a slight increase for total suspended solids. All the annual discharges were below the authorized/guideline levels.

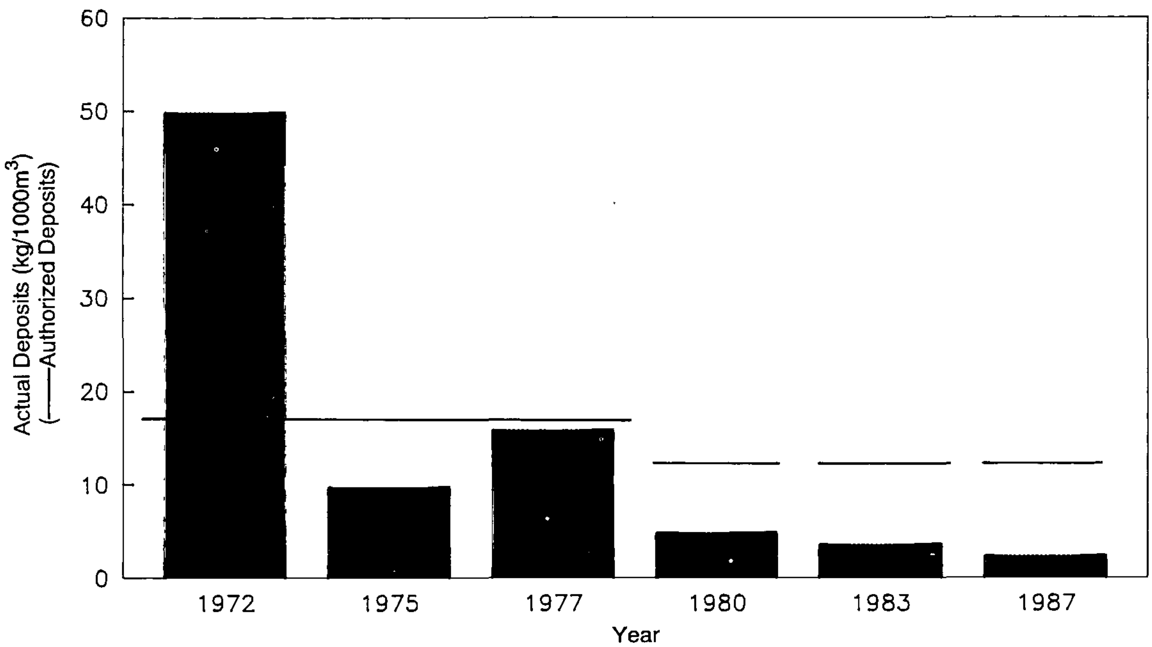


FIGURE 31 AVERAGE ANNUAL DISCHARGES OF OIL AND GREASE (Ontario Region - 1972 to 1987)

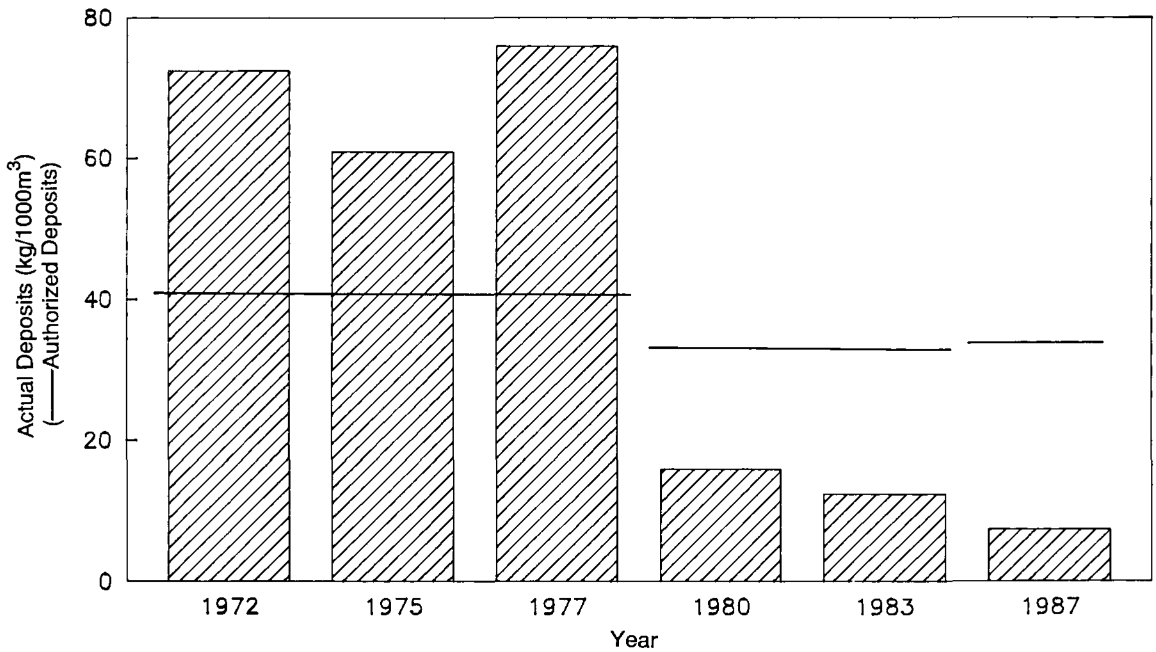


FIGURE 32 AVERAGE ANNUAL DISCHARGES OF TOTAL SUSPENDED SOLIDS (Ontario Region - 1972 to 1987)

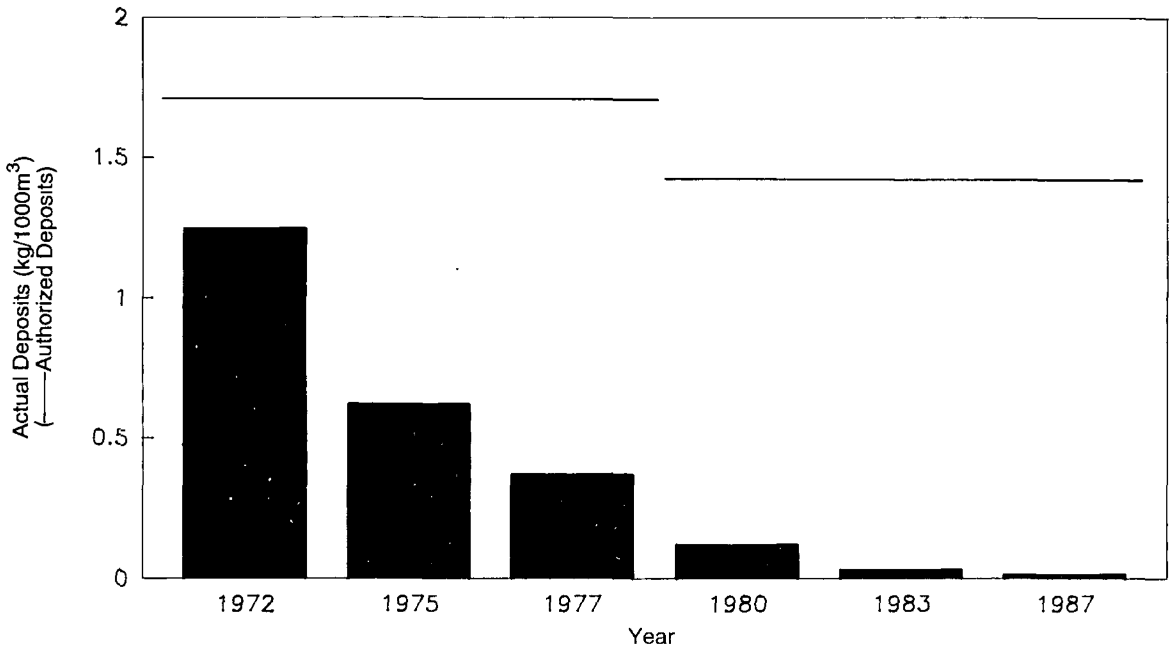


FIGURE 33 AVERAGE ANNUAL DISCHARGES OF PHENOLS (Ontario Region - 1972 to 1987)

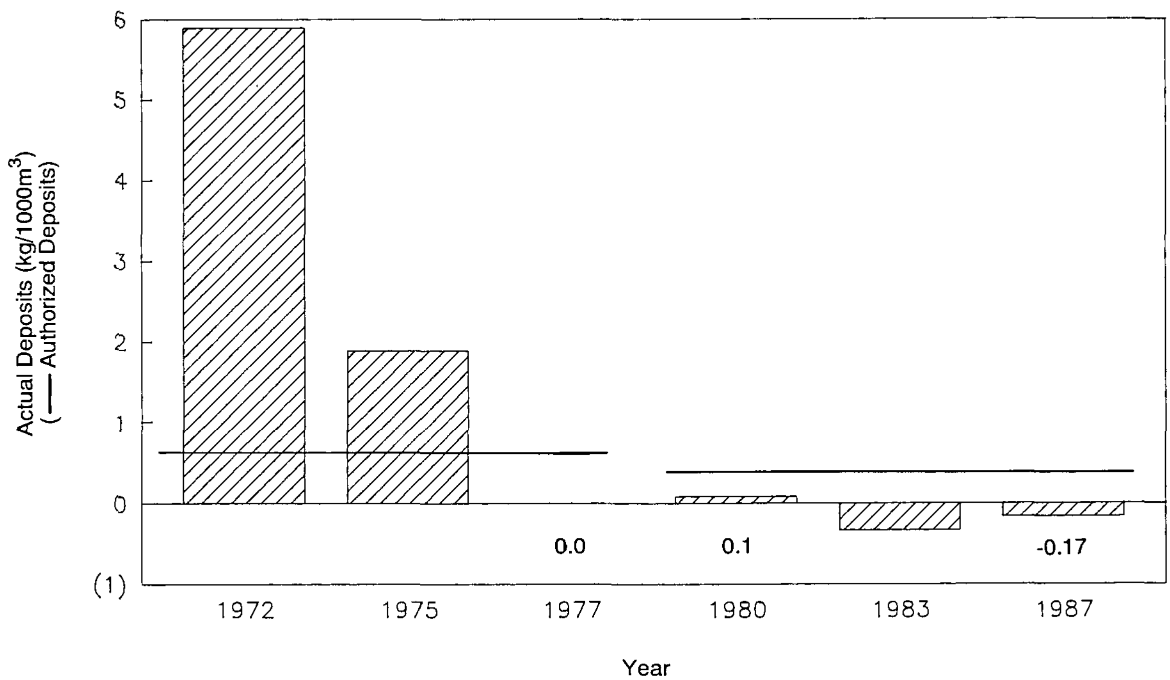


FIGURE 34 AVERAGE ANNUAL DISCHARGES OF SULPHIDE (Ontario Region - 1972 to 1987)

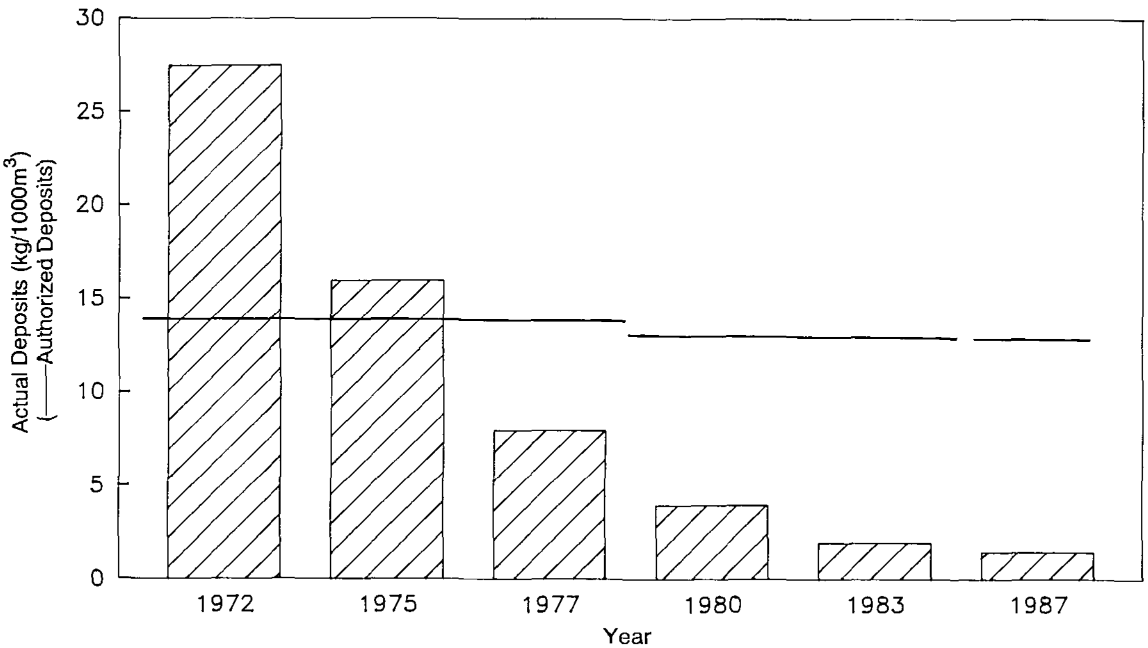


FIGURE 35 AVERAGE ANNUAL DISCHARGES OF AMMONIA NITROGEN (Ontario Region - 1972 to 1987)

As shown in Figures 36 to 40, the 1987 average deposits were below the monthly limits for all parameters in every refinery. Petrosar had the lowest discharge of oil and grease and Suncor had the highest; Texaco had the lowest level of total suspended solids and Suncor had the highest; all the refineries had very low levels of phenols and ammonia nitrogen; however, Texaco had the best performance for phenols and Shell--Corunna for ammonia nitrogen; the sulphide discharges were also very low for all the refineries except Petro-Canada, Trafalgar which had the highest level.

The two refineries that are subject to the regulations (Petrosar and Texaco) had a very good performance in 1987. Both were in full compliance for all parameters. However, Petrosar did not report the monitoring results for sulphide according to an agreement with the Ontario Ministry of the Environment. The annual deposits of these refineries were all very low compared to the authorized levels.

In the Sarnia area, total suspended solids are highly variable in the intake water. Solids appear to be trapped in cooling water systems and subsequently flushed out days later, leading to numerous deposits that exceed the daily suspended solids limit. The situation was discussed in 1983 and it was decided that the refineries in this area (Esso

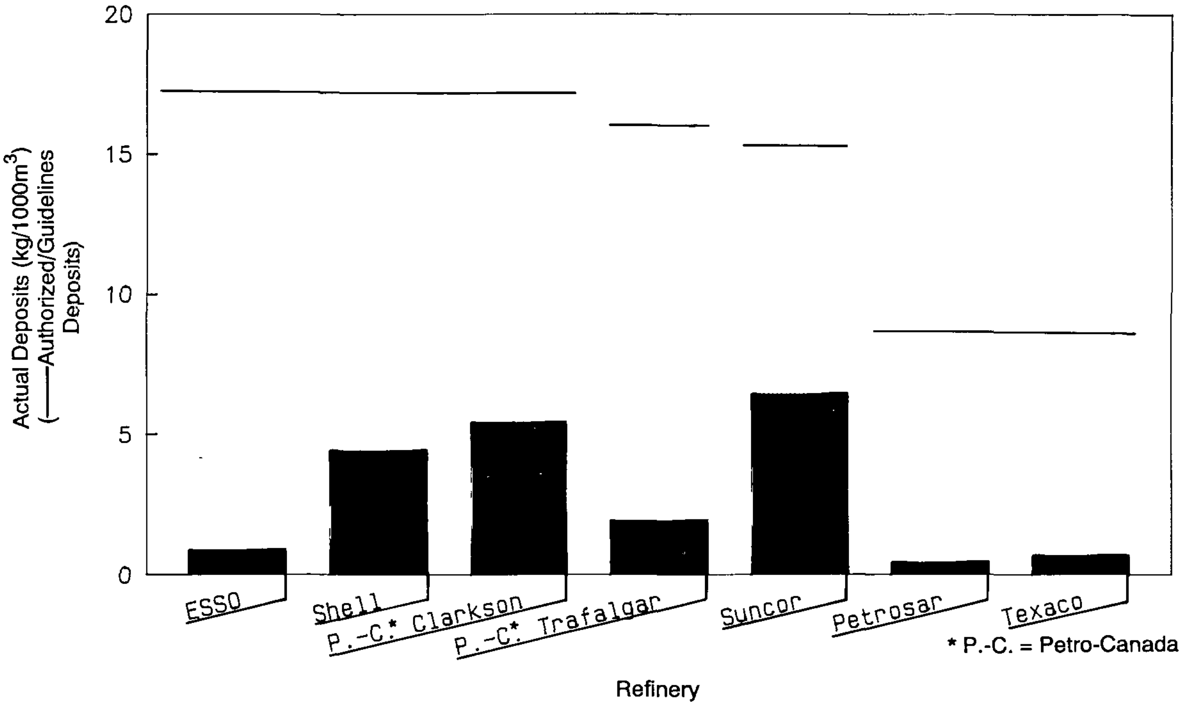


FIGURE 36 OIL AND GREASE DISCHARGE LEVELS BY REFINERY (Ontario Region - 1987)

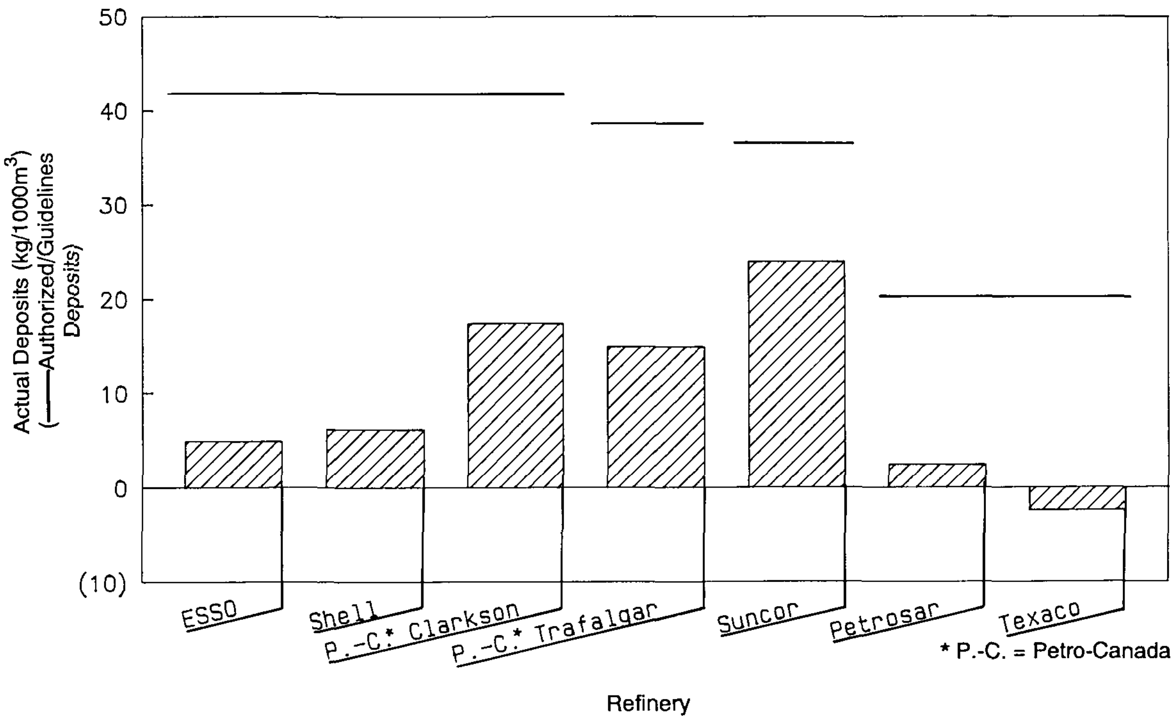


FIGURE 37 TOTAL SUSPENDED SOLIDS DISCHARGE LEVELS BY REFINERY (Ontario Region - 1987)

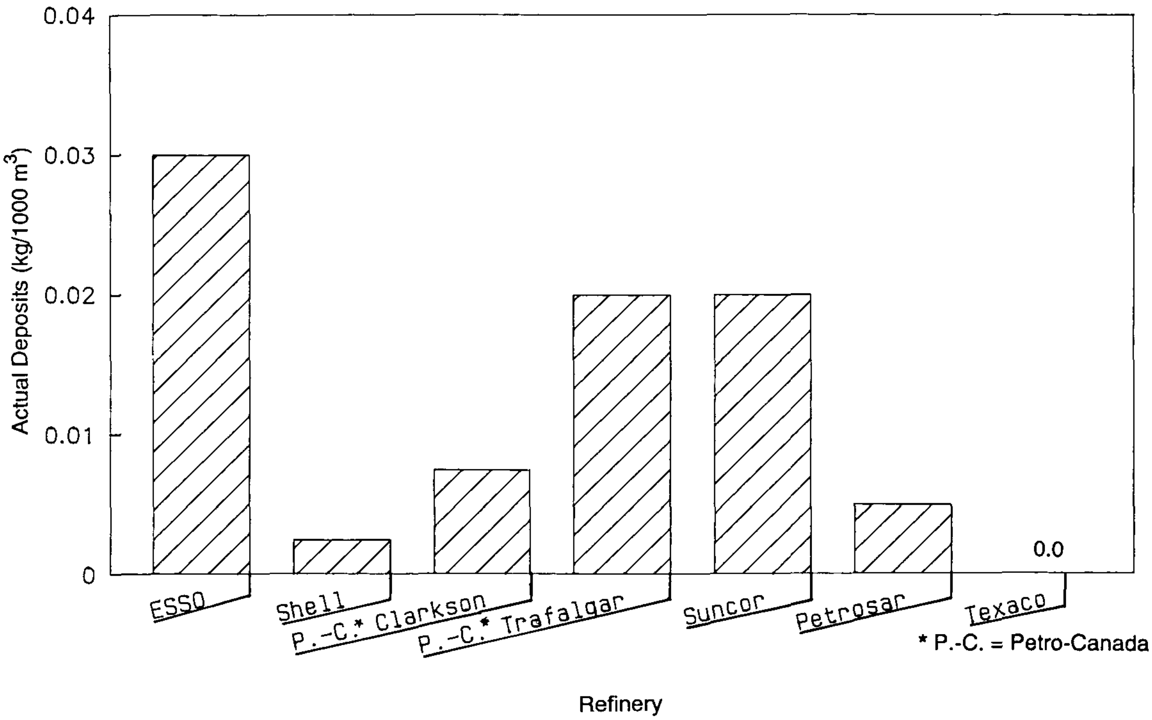


FIGURE 38 PHENOLS DISCHARGE LEVELS BY REFINERY (Ontario Region - 1987)

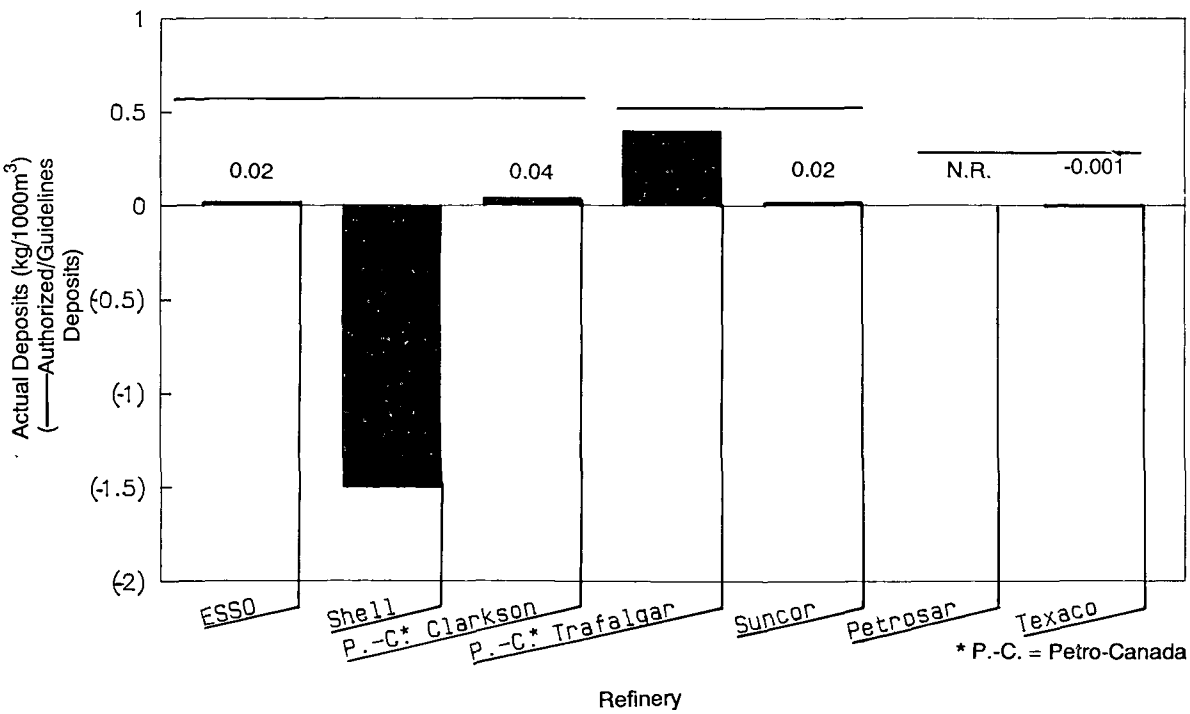


FIGURE 39 SULPHIDE DISCHARGE LEVELS BY REFINERY (Ontario Region - 1987)

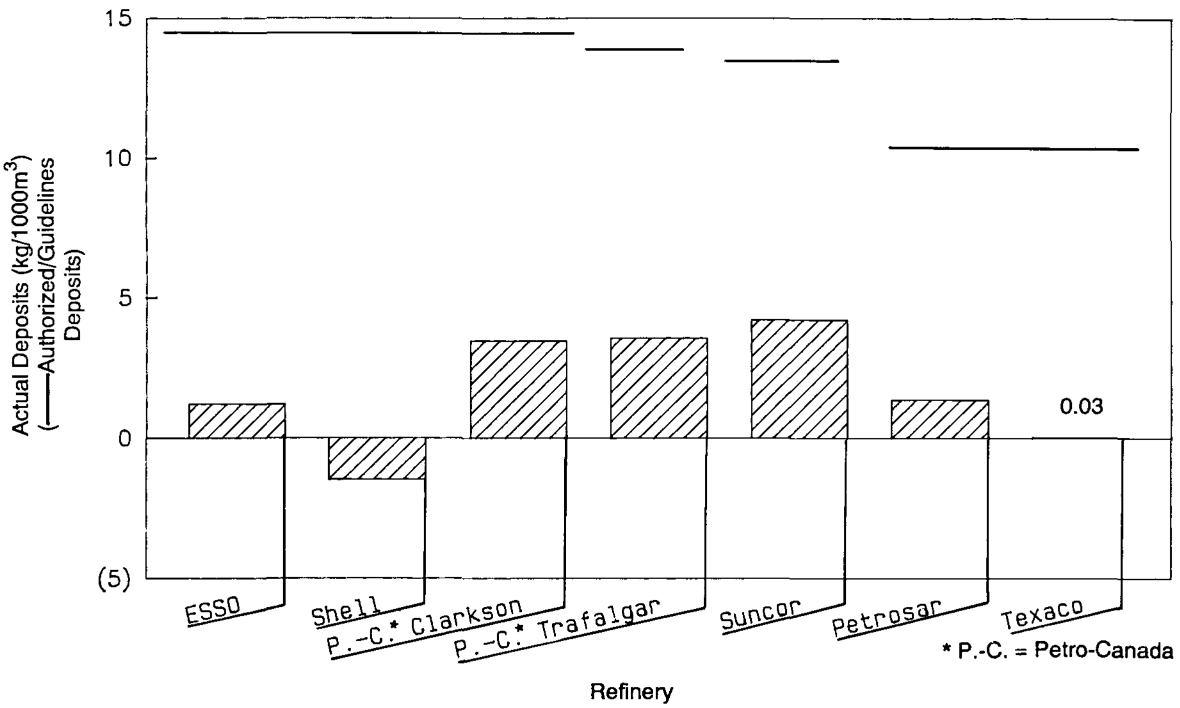


FIGURE 40 AMMONIA NITROGEN DISCHARGE LEVELS BY REFINERY (Ontario Region - 1987)

Petroleum, Petrosar, Shell and Suncor) would be granted the option of assessing total suspended solids only in process water and stormwater for the purpose of determining compliance with the federal regulations and guidelines. The option of substracting those suspended solids which front load into the system from the effluent has been proposed to obtain a net deposit. This option was used to assess Esso, Shell (Corunna) and Suncor.

Over fifteen percent of the tests required, mostly for sulphide and pH, were not reported in 1987. The regional crude production was reduced in 1987 by 7.6% from the 1983 level. This reduction was caused by the shutdown of Shell--Oakville and a lower crude rate at Suncor, Petrosar and both Petro-Canada refineries. The performance of each refinery in this region is presented in Table 17 which gives 1987 values for each parameter.

Esso-Petroleum--Sarnia. This refinery is closely affiliated with a chemical plant, Esso Chemical Canada. Although each facility has its own wastewater treatment system, some effluent from the chemical plant is treated in the refinery system. In addition, the chemical plant manufactures crude-based BTX (benzene, toluene and xylene) which is considered as a "refinery" product, and the generated effluent is treated at the chemical plant's system. As in the past, only the effluent that was treated at the refinery

TABLE 17 REFINERY FREQUENCY OF NON-COMPLIANCE WITH THE REGULATED PARAMETERS (Ontario Region - 1987)

	% of time not in compliance																			
	Oil and Grease				Total Suspended Solids				Phenols				Sulphide			Ammonia Nitrogen			pH	Toxicity
Refinery	M	O	N	S	M	O	N	S	M	O	N	S	M	O	N	M	O	N	N	N
Esso (Sarnia)	0	0	0		0	0	0		0	0	0		0	0	0	0	0	0	0	0
Shell (Corunna)	8.3	0.4	1.7		50	16	28		0	0	0		0	0	2.2	0	0	0	0	0
Petro-Canada (Trafalgar)	0	0	0		0	0	0		0	0	0		8.3	0	0	0	0	0	0	0
Petro-Canada (Clarkson)	0	0	0.3	8.0	0	1.1	1.4	0	0	0	0	0	0	0	0	0	1.7	2.5	0	0
Suncor (Sarnia)	0	0.6	0		8.3	1.5	2.2		0	0	0		0	0	0	8.3	1	2	0	0
Petrosar (Corunna)	0	0	0		0	0	0		0	0	0		NR	NR	NR	0	0	0	0	0
Texaco (Nanticoke)	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0

M : monthly amount; O : one-day amount; N : maximum daily amount; S : stormwater limits
NR : not reported

was considered for the 1987 compliance assessment. The refinery has a biological treatment system (activated sludge process) and discharges its effluent into the St. Clair River. Esso is subject to the guidelines and was in compliance in 1987 with the limits for all parameters. All annual averages of the monthly deposits were distinctly below the limits. Esso reported 82% of the tests requested.

Shell--Corunna. A biological oxidation unit (activated sludge) is used to treat the refinery effluent along with the effluent from an associated chemical plant. Effluent is then discharged into the Talfourd Creek (to the St. Clair River).

In 1987, Shell exceeded the limits set in the guidelines for oil and grease, total suspended solids and sulphide. Most excursions occurred for total suspended solids, the monthly amount was exceeded 50% of the time.

The overall performance in 1987 was 88% of the time in compliance with the monthly amounts and 98% with the daily limits. Of the seven monthly amounts that exceeded the limit, three were less than 50% above the guideline level, two were between 50 and 100% above the limit and the rest were between 100 and 200% above the limit. Negative annual average discharges were calculated in 1987 for sulphide and ammonia nitrogen. The negative averages were due to the highly variable nature of the upstream intake water which was often higher in concentration than the effluent. The annual deposits were below the monthly guideline levels for all parameters. The refinery reported only 60% of the requested tests. Very few measurements of total suspended solids, sulphide and ammonia nitrogen, or toxicity test results were reported (32% or less of the requested tests). Environment Canada had a discussion with Shell and the company will report all of the requested tests in the future. Recently, Shell added a third clarifier to their wastewater treatment system. This should reduce the total suspended solids deposits.

Petro-Canada—Trafalgar. This Petro-Canada refinery has an activated sludge process and discharges the effluent into Lake Ontario. Petro-Canada has an expanded status under the guidelines.

The refinery was in compliance in 1987 with all the limits except for one exceedance of the monthly amount for sulphides. The reason for the excursion was attributed to problems encountered with a new flow meter.

The 1987 annual average of the monthly deposits were all very low compared to the guideline limits. The refinery reported all the requested tests except for pH where 43% of the tests were not reported.

Petro-Canada—Clarkson. The Clarkson refinery treats its process and ballast water with an activated sludge system. The treated effluent is then discharged into Lake Ontario. A new sewer line was installed in 1986 to divert stormwater through the treatment plant enabling all stormwater to be treated. Modifications and upgrading of equipment in the refinery tank farm increased the ability to contain stormwater and control its release to the treatment plant. A wet slop injection system was installed to the desalter preventing the release of emulsified oils to the treatment plant.

In 1987, the refinery had an expanded status under the guidelines and was in complete compliance for phenols, sulphide, pH and toxicity. High amounts of suspended solids and ammonia were partly due to foul condensate entering the oily water sewers. Oil and grease exceeded the limits as a result of oil separation effluent carryover to the final effluent when the sand filter was backwashed. A malfunction of the air scout on the sand filters caused an exceedance of total suspended solids. The oil and grease monthly limit for stormwater was exceeded once.

The effluent quality has improved since 1983. There were no monthly amount excursions. Petro-Canada was in compliance with the daily limits more than 99% of the time, and 97% with the stormwater monthly limits. The noncompliant stormwater deposit exceeded the limit by a small amount. The annual average of the monthly deposits in 1987 were clearly below the limits for all parameters. The refinery reported almost 100% of the requested tests.

Suncor—Sarnia. This Suncor refinery treats its wastewater in a secondary treatment system and discharges the effluent into the St. Clair River. The wastewater treatment facility was upgraded during 1986. A second aeration basin for biological treatment has been added to treat contaminated stormwater. In the old aeration basin a new concrete floor has been installed. Both the new and old aeration basin have sub-surface diffusers for biological treatment. A second impounding basin was constructed to the north of the original to hold storm overflow for reworking through the treatment system. Both of the impounding basins had polyethylene liners installed to prevent erosion and leachate.

Suncor is subject to the guidelines and had an expanded status for 1987. The refinery was in full compliance for phenols, sulphide, pH and toxicity. Excursions occurred for total suspended solids, ammonia nitrogen, and oil and grease. The company was in compliance with the monthly amounts 97% of the time.

The overall performance of Suncor was very good in 1987. The refinery was 97% of the time in compliance with the monthly amounts as opposed to 100% in 1983. However, Suncor was in compliance with the other two daily limits more than 99% of the time, the same level as 1983. The ammonia nitrogen deposit in excess of the monthly amounts was less than 50% above the limit and the total suspended solids deposit in excess was less than 25% above the limit. All five parameters had very low annual deposits compared to the monthly guideline levels. The refinery did not report enough tests for sulphide (71% were not reported) and for pH (31% were not reported); all the requested tests were reported for the other parameters.

Petrosar—Corunna. Petrosar is a new refinery and was, therefore, subject to the regulations. The refinery also has petrochemical processes and treated both effluents in the same system which consisted of a biological oxidation unit followed by a tertiary system (activated carbon filters). The effluent is then discharged into the St. Clair River.

In 1987, the refinery was in compliance 100% of the time for all parameters. The annual deposits were all well below the monthly authorized levels. The refinery did not report any sulphide tests which is a violation of the reporting requirements. However, in 1985, the company reinstalled sulphide testing. Sulphides are monitored by Petrosar, however, they have not been reported by Petrosar since 1979 as a result of an agreement with the Ontario Ministry of the Environment.

Texaco--Nanticoke. The new Texaco refinery in Nanticoke is subject to the regulations. The refinery has an activated sludge unit followed by a tertiary treatment consisting of an effluent filtration unit. The treated effluent is discharged into Lake Erie.

During 1987, Texaco was in complete compliance for all parameters. All stormwater discharges were less than the annual allowable loadings. The refinery provided all the tests that were required except for pH where only 2% was not reported.

3.4.5 **Western & Northern Region Assessment.** Five refineries in this region were subject to the guidelines and three of these refineries had an expanded status. In addition, the region has four new refineries (Turbo, Husky, Esso--Edmonton, and Shell -- Scotford). New refineries must comply with the more stringent regulation limits. However, Husky and Turbo were only assessed for their stormwater discharges because their process effluents are deep-well injected. In Alberta, the provincial requirements for an effluent that is deep-well injected are stricter than the federal effluent regulations and guidelines. The effluents from two refineries (Petro-Canada--Moose Jaw; and Co-op--Regina) are further treated off-site at municipal facilities. Shell-Bowden did not discharge any effluent in 1987. See Appendix B for individual performances.

In 1987, on average, the region was in compliance with the monthly amounts of the guidelines 82% of the time, and of the regulations, 100% of the time. The refineries subject to the guidelines had difficulty with most parameters except toxicity and pH for which they were in full compliance. One refinery (Petro-Canada--Edmonton) was in full compliance with the monthly amounts and daily limits. The refineries having the lowest performance with respect to monthly amounts were: Co-op, in compliance only 60% of the time; and Esso--Norman Wells, 77% of the time. As shown in Table B-5 (Appendix B), 30% of the deposits that exceeded the monthly and stormwater amounts were more than 200% above the limit. The region was also in compliance 88% with the monthly amounts, more than 98% of the time with the one-day amounts and 99% with the maximum daily amounts.

Compared to 1983, the 1987 regional performance improved. Less deposits exceeded the monthly amounts and the two daily limits. The annual deposits were smaller for most of the parameters, oil and grease stayed at the same level and deposits for phenols increased by 36% compared to 1983.

The regional annual deposits from 1972 to 1987 are presented in Figures 41 to 45. Most of the 1987 discharge levels decreased compared to those of 1983. The regional levels were below the authorized/guideline limits for all parameters.

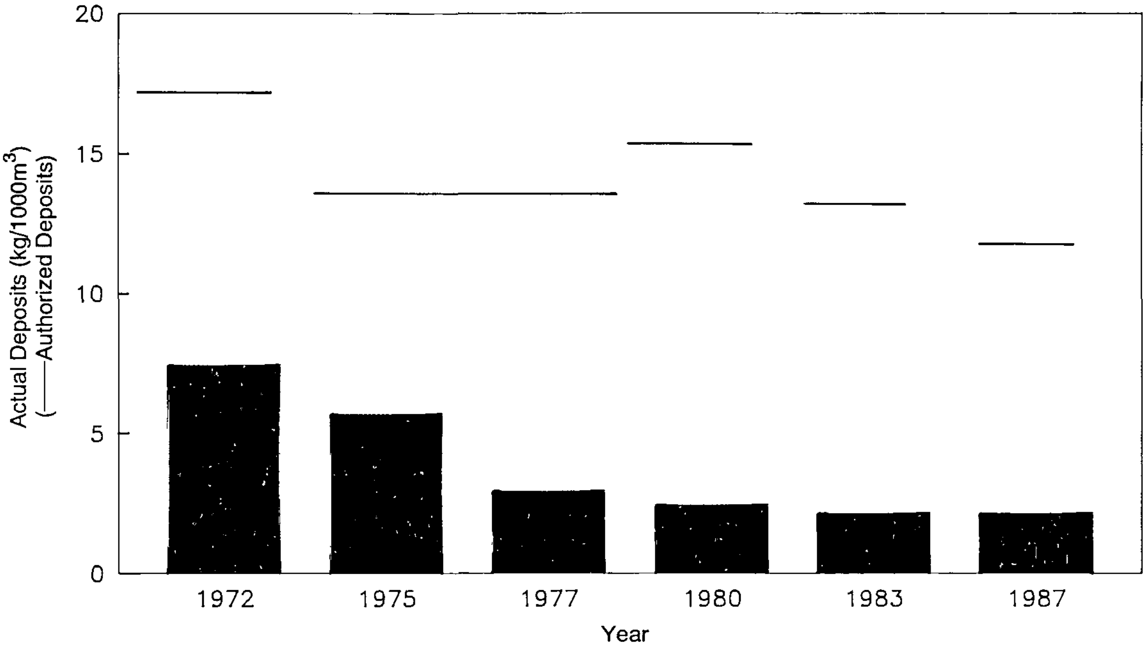


FIGURE 41 AVERAGE ANNUAL DISCHARGES OF OIL AND GREASE (Western & Northern Region 1972 to 1987)

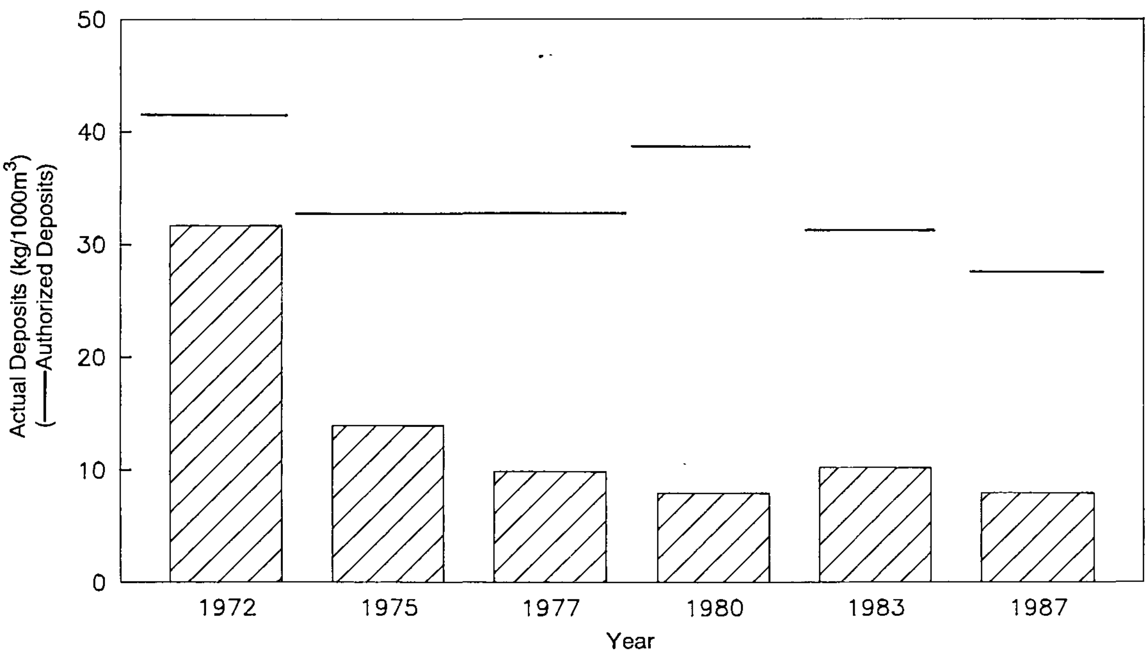


FIGURE 42 AVERAGE ANNUAL DISCHARGES OF TOTAL SUSPENDED SOLIDS (Western & Northern Region 1972 to 1987)

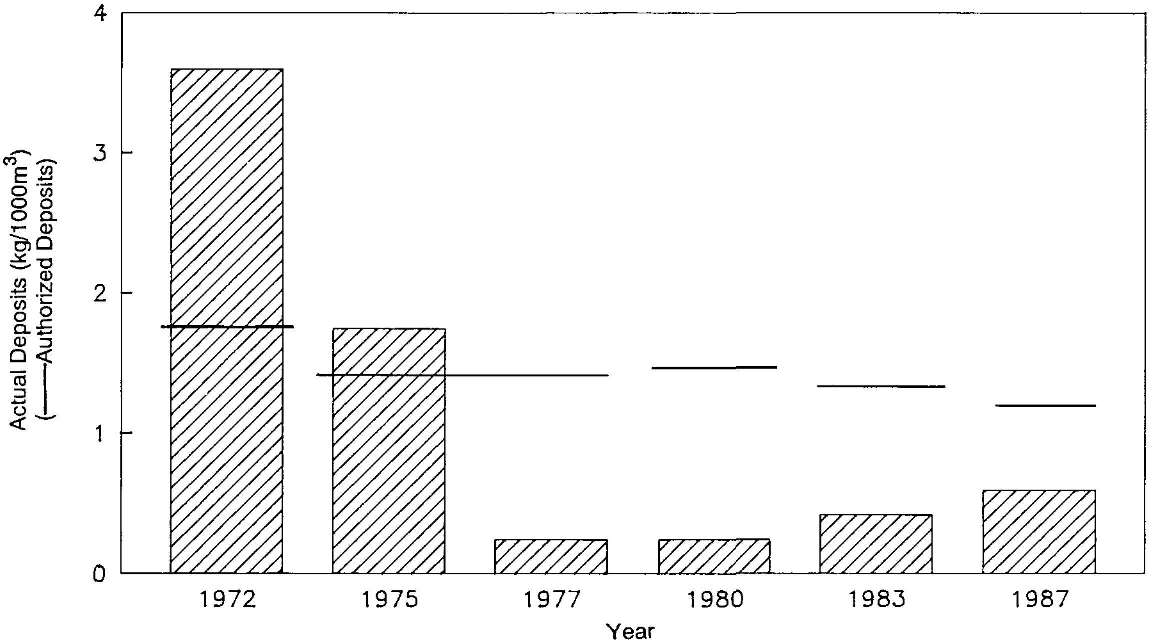


FIGURE 43 AVERAGE ANNUAL DISCHARGES OF PHENOLS (Western & Northern Region 1972 to 1987)

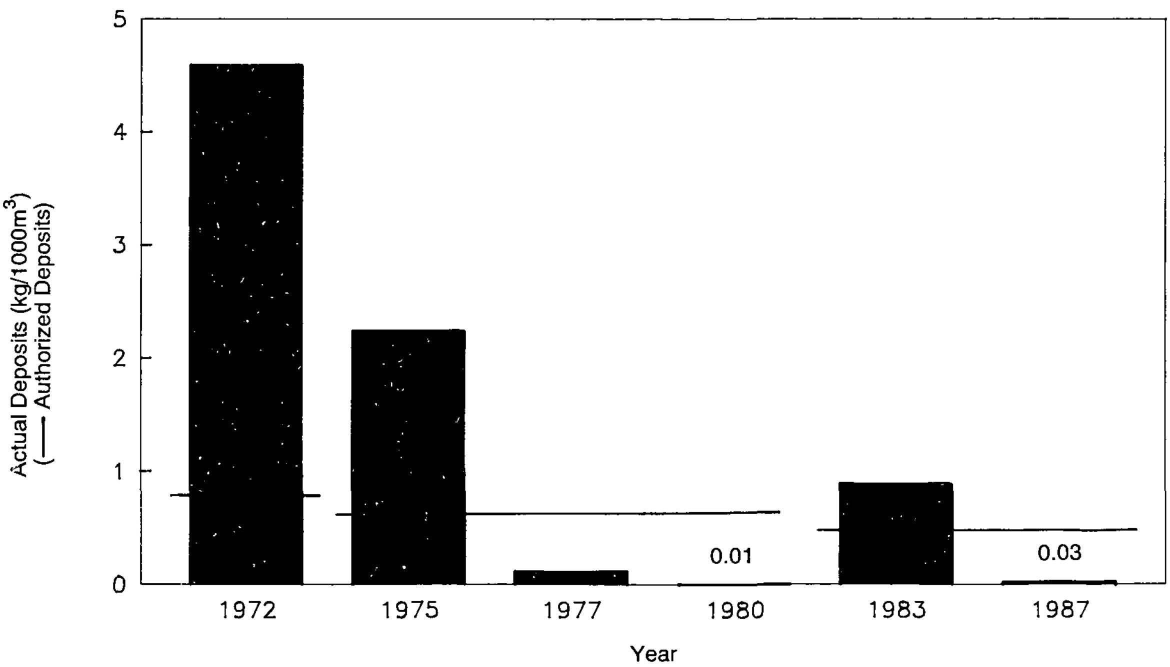


FIGURE 44 AVERAGE ANNUAL DISCHARGES OF SULPHIDE (Western & Northern Region 1972 to 1987)

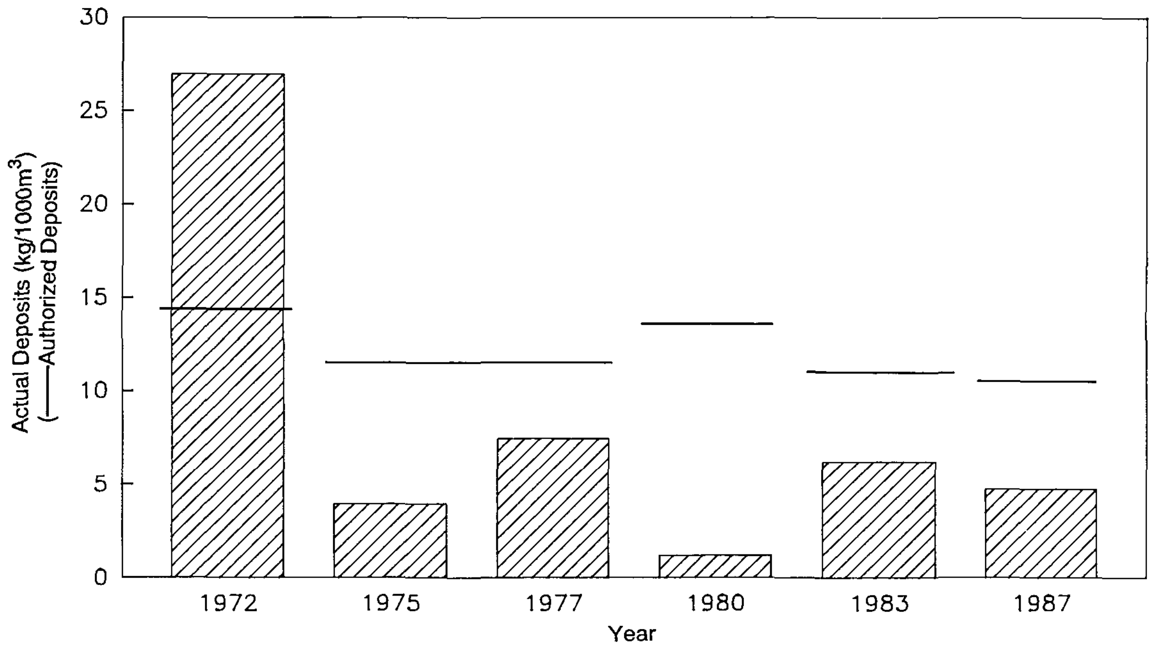


FIGURE 45 AVERAGE ANNUAL DISCHARGES OF AMMONIA NITROGEN (Western & Northern Region 1972 to 1987)

The annual deposits for all the refineries in the region are presented in Figures 46 to 50. There was always one refinery over the authorized deposits for four out of five parameters. For oil and grease, Esso--Norman Wells was above the limit and Petro-Canada--Edmonton had the lowest discharge. Although the total suspended solids limit was exceeded by Esso--Norman Wells, the high levels present in the MacKenzie River (used for intake water) were responsible for this exceedance. Esso--Edmonton had the lowest suspended solids discharge. The Co-op refinery exceeded the phenols and the ammonia nitrogen limits. Sulphide discharges never exceeded the authorized deposits. Discharges were all well below the limits; Petro-Canada--Edmonton had the lowest sulphide level.

Of all the required tests in the region, 57% were not reported in 1987. The number of unreported tests ranged from 44% for pH to 76% for ammonia nitrogen. The overall production in 1987 was increased by 11% from the 1983 level. The performance of each refinery in this region is presented in Table 18 giving the 1987 value for each parameter.

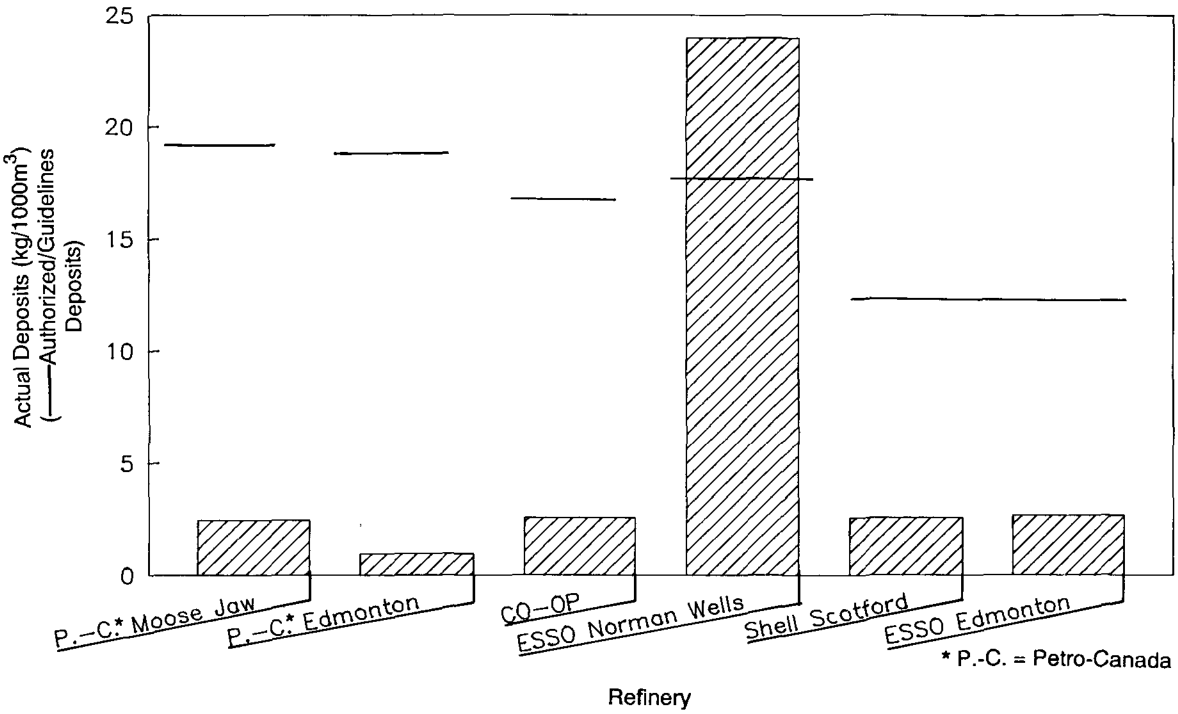


FIGURE 46 OIL AND GREASE DISCHARGE LEVELS BY REFINERY (Western & Northern Region - 1987)

FIGURE 47 TOTAL SUSPENDED SOLIDS DISCHARGE LEVELS BY REFINERY (Western & Northern Region - 1987)

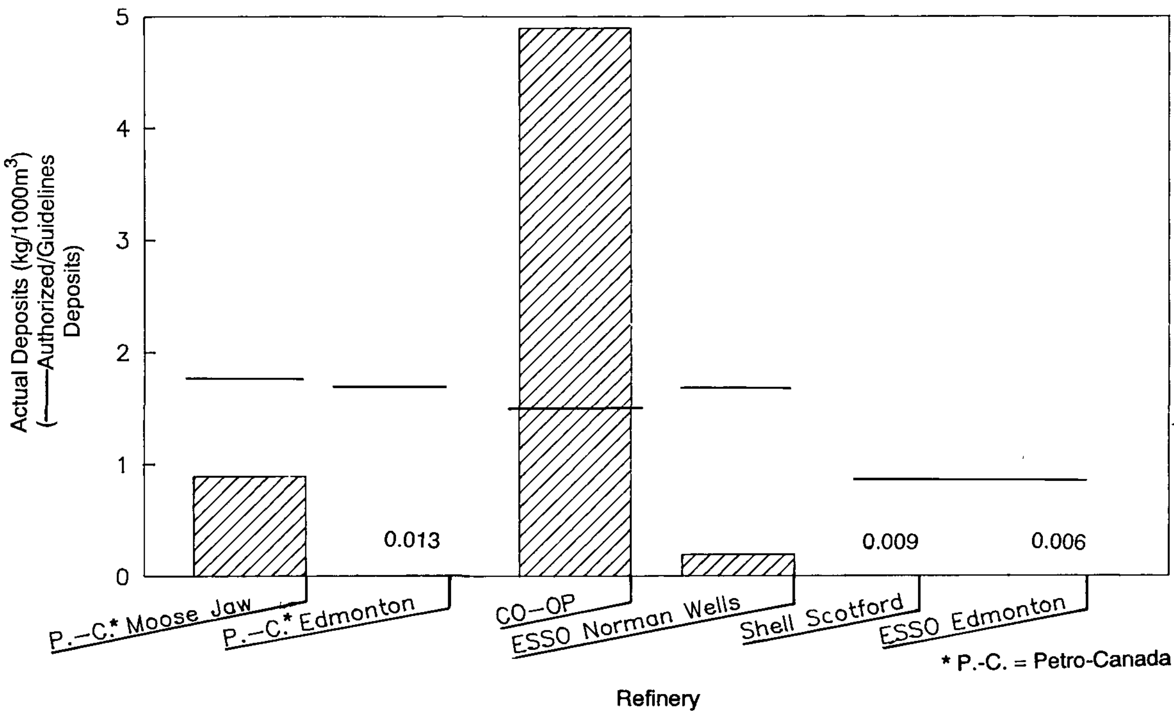


FIGURE 48 PHENOLS DISCHARGE LEVELS BY REFINERY (Western & Northern Region - 1987)

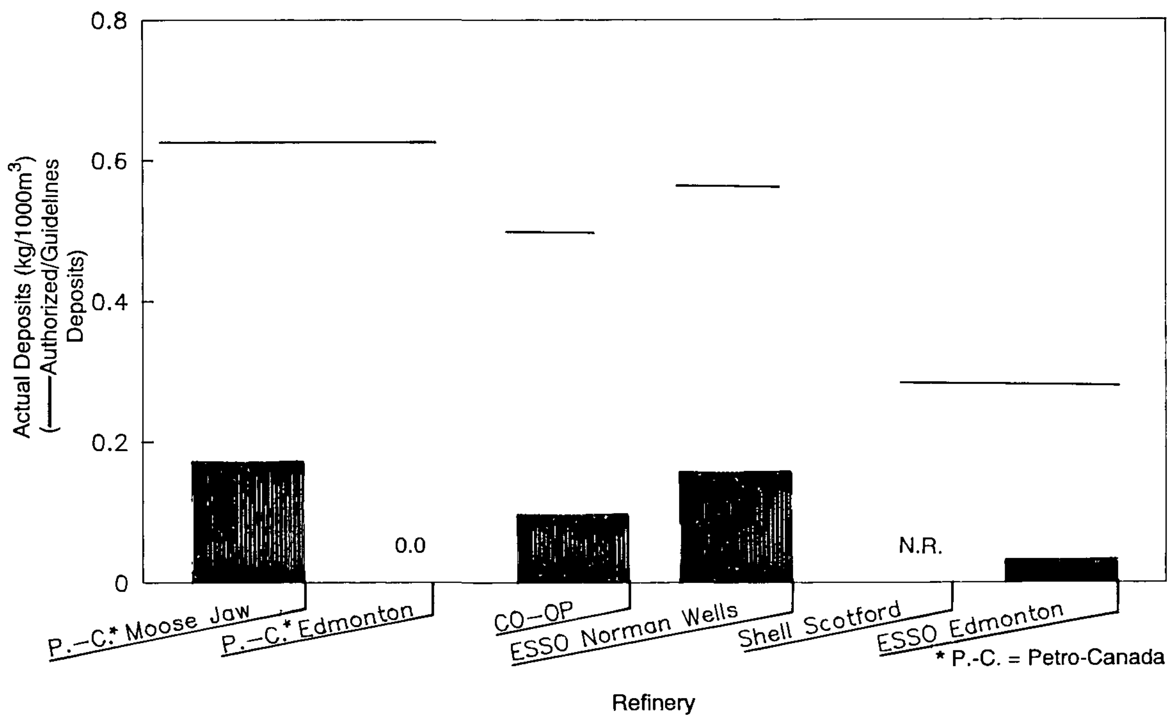


FIGURE 49 SULPHIDE DISCHARGE LEVELS BY REFINERY (Western & Northern Region - 1987)

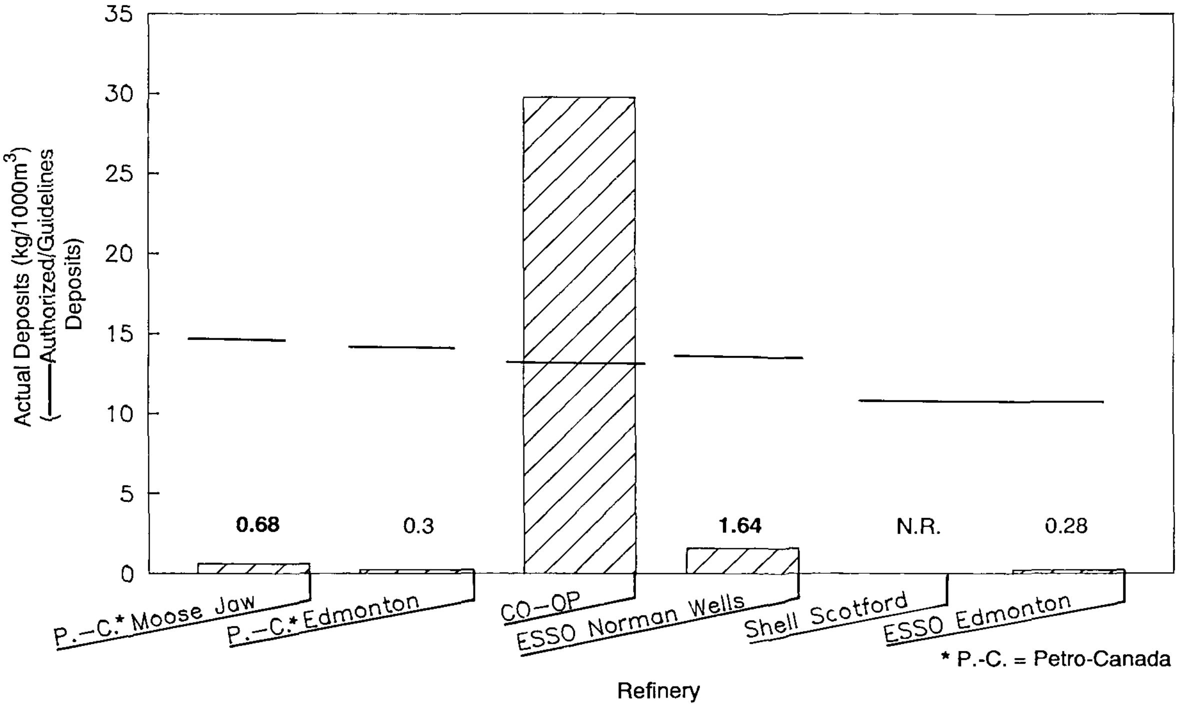


FIGURE 50 AMMONIA NITROGEN DISCHARGE LEVELS BY REFINERY (Western & Northern Region - 1987)

TABLE 18 REFINERY FREQUENCY OF NON-COMPLIANCE WITH THE REGULATED PARAMETERS (Western & Northern Region - 1987)

	% of time not in compliance																
	Oil and Grease			Total Suspended Solids			Phenols			Sulphide			Ammonia Nitrogen			pH	Toxicity
Refinery	M	O	N	M	O	N	M	O	N	M	O	N	M	O	N	N	N
Petro-Canada (Edmonton)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Petro-Canada (Moose Jaw)	0	NR	NR	0	NR	NR	12.5	NR	NR	12.5	NR	NR	0	NR	NR	0	NR
Esso Petroleum (Norman Wells)	50	5.8	9.6	66.7	26.5	32.7	0	0	0	0	0	0	0	0	0	0	0
Co-op (Regina)	0	NR	NR	0	NR	NR	100	NR	NR	0	NR	NR	100	NR	NR	0	NR
Esso Petroleum (Edmonton)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shell (Scotford)	0	0	0	0	0	0	0	0	0	NR	NR	NR	NR	NR	NR	0	0

NR - not reported
M - monthly amount; O - one-day amount; N - maximum daily amount

Petro-Canada—Edmonton, Alta. The Petro-Canada refinery in Edmonton has a primary treatment system and a retention pond. The refinery discharges its effluent into the North Saskatchewan River. Some wastes such as oily water from process areas are treated and deep-well injected. Petro-Canada was considered an existing refinery subject to the guidelines in 1987.

Petro-Canada performed very well in 1987. The refinery was in compliance for all parameters 100% of the time. All of the annual deposits were significantly below the limits. The refinery did not report 46% of the tests requested; for most of parameters, more than 65% of the tests were missing.

Petro-Canada--Moose Jaw, Sask. This refinery has a primary treatment system and the effluent is treated further at the municipal treatment plant. However, Petro-Canada did not receive an exemption from the guidelines. Part of Petro-Canada's treated stormwater is discharged to Moose Jaw Creek. The refinery has an existing status and is subject to the guidelines.

Petro-Canada was in compliance in 1987 for all parameters except for one monthly sulphide deposit and one monthly phenol deposit. The phenol deposit was less than 25% above the limit and the sulphide deposit was less than 50% above the limit. However, the off-site effluent treatment would normally reduce the sulphide level. This evaluation is not a good indication of Petro-Canada's performance because only one test per month was performed for each parameter rather than the requested three tests per week for the five parameters and one test per day for pH. The low number of tests made it impossible to assess compliance with the daily limits. In addition, Petro-Canada did not perform any toxicity tests. In 1987, the annual deposits were all below the limits.

Esso Petroleum--Norman Wells, NWT. The Esso refinery in Norman Wells has an API separator as a primary treatment system and the effluent is discharged into the Mackenzie River. The refinery is subject to the guidelines and has existing status.

The main problem in 1987 lay with oil and grease, and total suspended solids. For these two parameters, the monthly amounts were exceeded 50% of the time and 67% of the time, respectively; the daily limits were also exceeded. The one-day amount of oil and grease was exceeded 6% of the time and suspended solids 26%; the maximum daily amount of oil and grease was exceeded 10% of the time and suspended solids 33% of the time. The refinery was in compliance for all other parameters.

The 1987 annual average deposits of oil and grease and total suspended solids were both higher than the authorized levels. This has been an ongoing problem at Esso. An 18-week survey carried out by the company in 1984 indicated that the high solids concentration in the Mackenzie River, which supplies water to the refinery, caused the high total suspended solids readings. The company will be reminded of the net value concept contained in the petroleum refinery effluent guidelines. Once-through cooling water is sent with the liquid effluent to the API separator in this refinery, and therefore solids measured in the effluent contain solids from the cooling water. The oil and grease excursions were mainly due to the API separator and improper chemical use in Battery 3; the problem has been rectified.

Overall performance in 1987 was 77% of the time in compliance with the monthly amounts, 94% with the one-day amounts and more than 93% with the maximum daily amounts. Fifty percent of the deposits that exceeded the monthly amounts were less than 100% above the limit, 21% were between 100 and 200% above the limit and the rest were more than 200% above the limit.

Esso has been monitoring its effluent once per week for each chemical parameter and twice per year for toxicity according to the Northwest Territories Water Board requirements pursuant to the Northern Inland Waters Act. Based on the Water Board requirements, Esso reported 98% of the tests in 1987.

Shell--Bowden, Alta. The Shell refinery in Bowden had an existing status and was subject to the guidelines. Shell had a primary treatment system (API separator) and discharged its effluent on an intermittent basis to a drainage ditch which leads to the Red Deer River. In 1987, the refinery did not discharge any effluent into the river.

Co-op--Regina, Sask. This Consumers Co-op refinery has a primary treatment system and discharges its effluent to the Regina Municipal sewer for further treatment. The refinery has an expanded status and is subject to the guidelines.

The Co-op was in compliance "at the refinery fence" in 1981 and was, therefore, given a two-year exemption in 1982 from the normal reporting requirements under the federal refinery effluent guidelines. The exemption allowed Co-op to report only tri-monthly averages of its effluent, and toxicity tests were not required. Since 1982, however, effluent quality has deteriorated considerably. In view of the unsatisfactory effluent quality of 1983 and 1984, Co-op was not granted another exemption.

In 1987, Co-op was in compliance for oil and grease, total suspended solids, sulphide and pH. However, the refinery exceeded the monthly limits 100% of the time for phenols and ammonia nitrogen. The company has not yet provided any evidence that the off-site treatment achieves an adequate reduction. The company only reported monthly averages, it was therefore impossible to evaluate the compliance with the two daily limits.

The refinery's performance in 1987 has not improved from 1983. Deposits of total suspended solids, phenols and ammonia nitrogen increased. Annual deposits were above the guideline levels for phenols and ammonia nitrogen. Co-op performed only 21% of the required tests, no toxicity test was done and only monthly averages were reported.

Esso-Petroleum--Edmonton, Alta. Esso Petroleum in Edmonton is a new refinery and is subject to the regulations. The refinery has a secondary treatment system consisting of an aerated lagoon and the effluent is discharged into the North Saskatchewan River. In addition, Esso is authorized by Alberta Environment to use deep-well injection for brine and other process water.

In 1987, Esso was 100% in compliance for all parameters. All of the annual deposits were well below the authorized limits; an improvement from 1983. The refinery reported all the tests required by their provincial license; however, this represents only 54% of the tests required by the federal regulations.

Shell-Scotford, Alta. The Scotford refinery started operation in September 1984. In December 1984, the refinery began discharging effluent and stormwater (on a periodic basis).

Thhe company was in compliance with all the limits for all parameters. One test per week was performed for oil and grease, total suspended solids, phenols and pH, one tri-monthly test for toxicity. The province does not require the company to report sulphide and ammonia nitrogen. The company reported 65% of the tests required by the federal regulations. The annual deposits were all below the authorized limits.

Turbo--Balzac, Alta. Turbo is a new refinery and is subject to the regulations. However, the refinery deep-well injected its process effluent so only the stormwater was assessed. The stormwater was discharged into McDonald Lake. The company was in full compliance and all stormwater discharges were below the authorized level.

Husky-Lloydminster, Alta. Husky is a new refinery and is subject to the regulations. The process effluent was deep-well injected in 1987, so only stormwater discharges were assessed.

The comapny was in full compliance and all stormwater deposits were below the authorized levels. The stormwater was discharged into the North Saskatchewan River for only 6 days in October 1987.

3.4.6 **Pacific & Yukon Region Assessment.** In 1987, six refineries were operating in British Columbia that were to the guidelines. Only one (Chevron) had an expanded status; the others had an existing status. Four of the six refineries discharged their effluents to off-site treatment systems. The extent to which the municipal sewage treatment plants which receive the refineries' effluent provide adequate treatment has yet to be determined. None of these refineries have applied for exemptions from the controls or from the normal monitoring requirements of the guidelines. The Petro-Canada refinery at Taylor also treats the effluent generated by associated tank farm, gas plant, sulphur plant and liquid natural gas plant. The performance of each refinery in 1987 is summarized in Appendix B.

In 1987, the region was in compliance with the monthly amounts 97% of the time. Four refineries were in compliance with the monthly amounts 100% of the time. The other two, Shell and Chevron were both in compliance 90% of the time. Shell's and Chevron's effluents receive further treatment offsite. As shown in Table B-6 (Appendix B), 75% of the deposits that exceeded the monthly amounts and the stormwater limits were less than 50% above the limit, 19% were between 50 and 99% above the limit and 3% were more than 200% above the limit. In addition, the region was in compliance 99.9% of the time with the one-day amounts, more than 98% of the time with maximum daily amounts and 86% with the stormwater limits. The parameters that were exceeded most were total suspended solids and pH. Discharges of total suspended solids exceeded the monthly amount 7% of the time and the pH tests failed 8% of the time.

In 1987, overall regional performance was superior to that of 1983. The actual number of deposits that exceeded the limits decreased for phenols, sulphide, ammonia nitrogen and toxicity. It increased for oil and grease, total suspended solids and pH. Compliance with the monthly amounts (of all parameters) increased from 95% in 1983 to 97% in 1987. There were also fewer deposits exceeding the daily limits. However, stormwater deposits in excess of the limits increased in 1987. The deposits were in compliance with the limits 92% of the time in 1983 and 86% of the time in 1987.

The annual average of regional deposits from 1972 to 1987 is illustrated in Figures 51 to 55. As shown, there was a reduction in the 1987 discharges of two parameters (phenols and ammonia nitrogen) compared to the 1983 levels. Reductions of deposits ranged from a maximum of 51% for phenols to 16% for ammonia nitrogen. Increases of deposits ranged from 48% for total suspended solids to 10% for oil and grease. However, the discharge levels for 1987 were all below the authorized limits.

A comparison of the 1987 yearly deposits for the refineries in the region is presented in Figures 56 to 60. All the annual deposits of the refineries were below the authorized levels. Oil and grease deposits were generally very low; Husky had the lowest level and Shell had the highest. For total suspended solids, Chevron had the highest

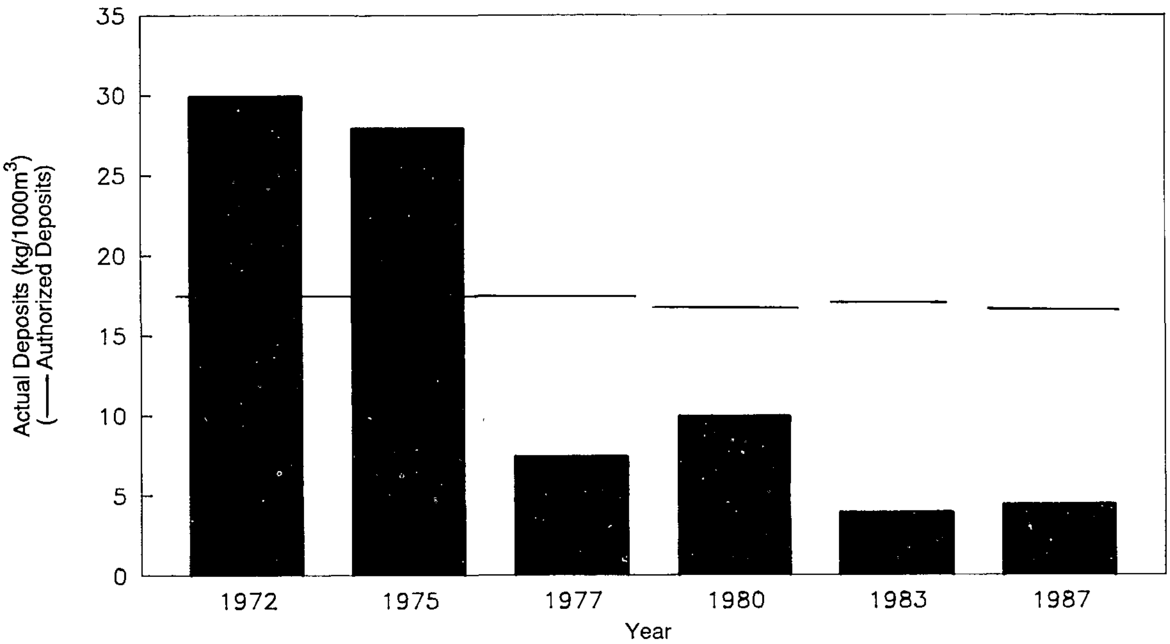


FIGURE 51 AVERAGE ANNUAL DISCHARGES OF OIL AND GREASE (Pacific & Yukon Region - 1972 to 1987)

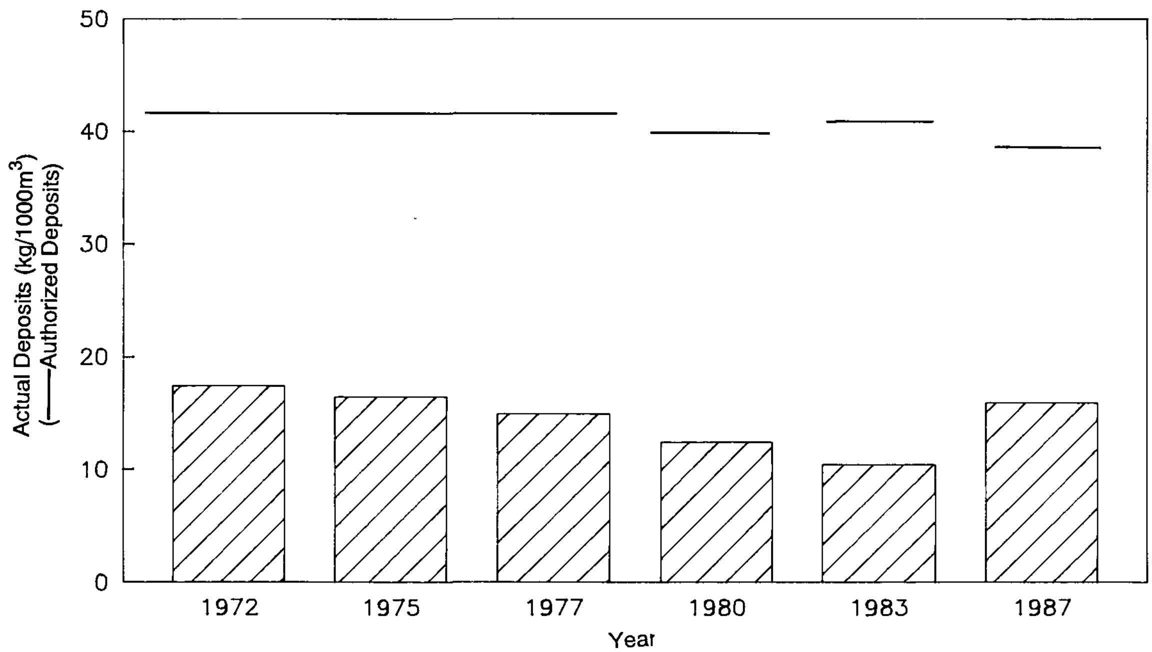


FIGURE 52 AVERAGE ANNUAL DISCHARGES OF TOTAL SUSPENDED SOLIDS (Pacific & Yukon Region - 1972 to 1987)

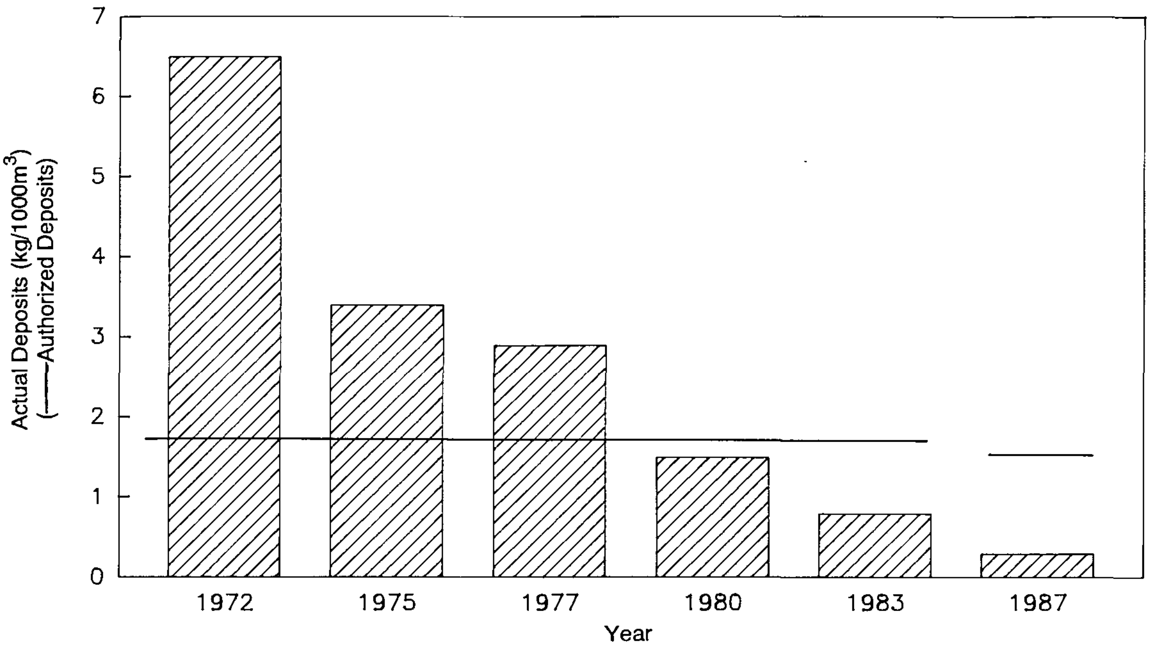


FIGURE 53 AVERAGE ANNUAL DISCHARGES OF PHENOLS (Pacific & Yukon Region - 1972 to 1987)

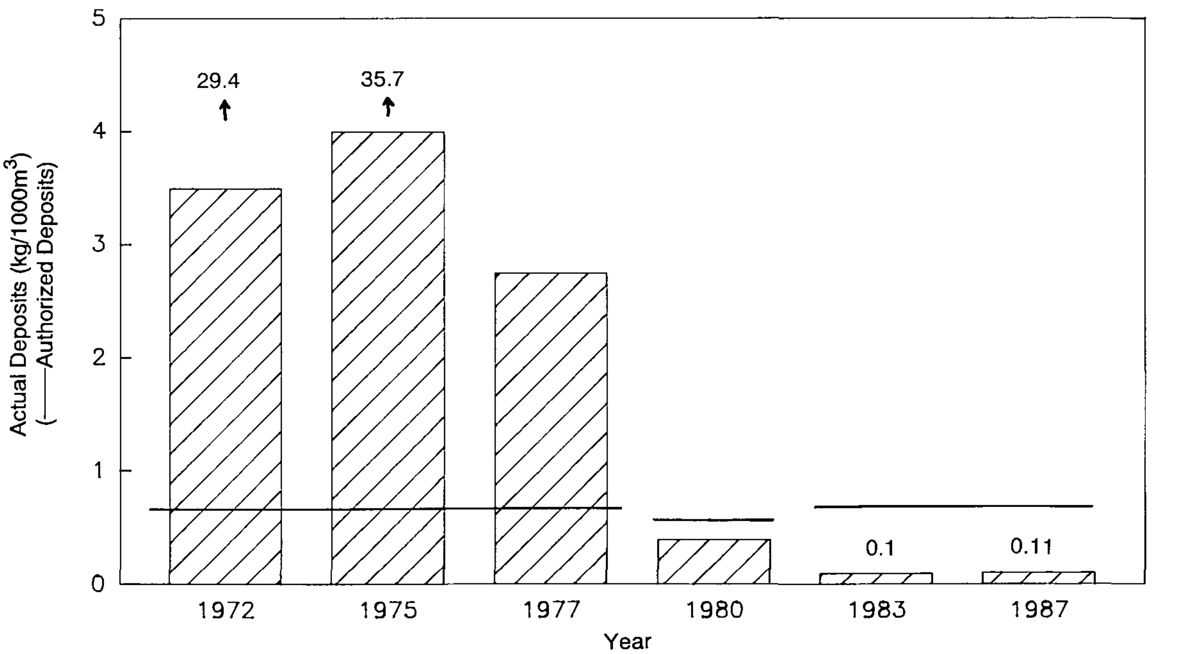


FIGURE 54 AVERAGE ANNUAL DISCHARGES OF SULPHIDE (Pacific & Yukon Region - 1972 to 1987)

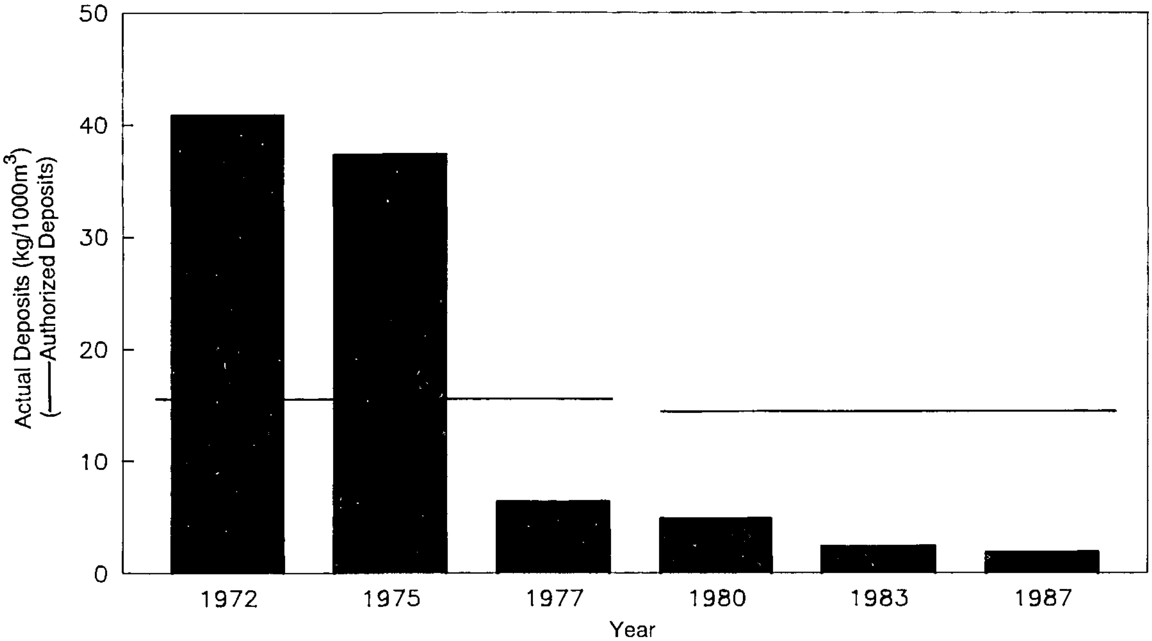


FIGURE 55 AVERAGE ANNUAL DISCHARGES OF AMMONIA NITROGEN (Pacific & Yukon Region - 1972 to 1987)

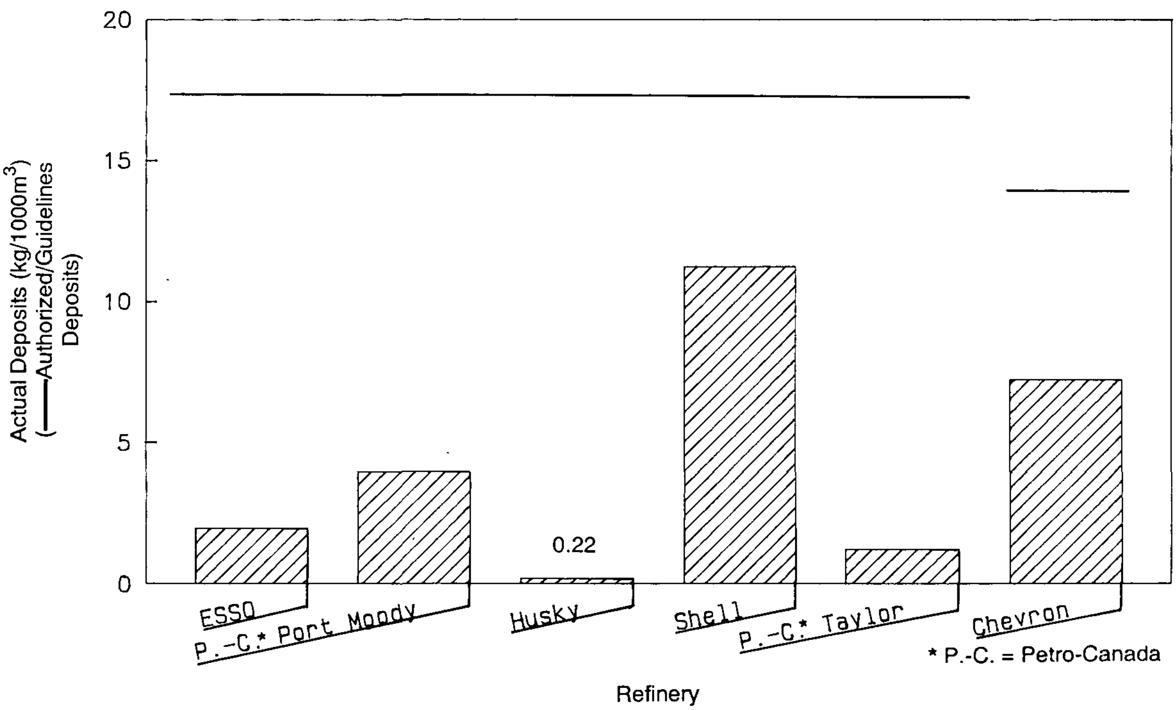


FIGURE 56 OIL AND GREASE DISCHARGE LEVELS BY REFINERY (Pacific & Yukon Region - 1987)

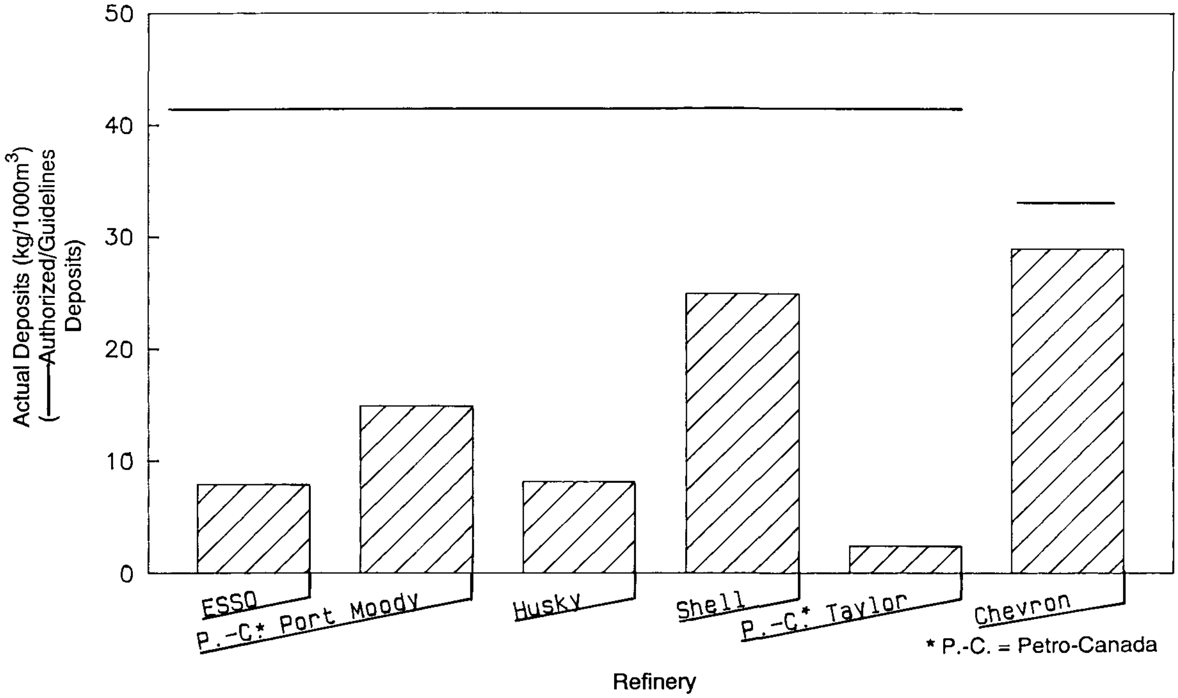


FIGURE 57 TOTAL SUSPENDED SOLIDS DISCHARGE LEVELS BY REFINERY (Pacific & Yukon - 1987)

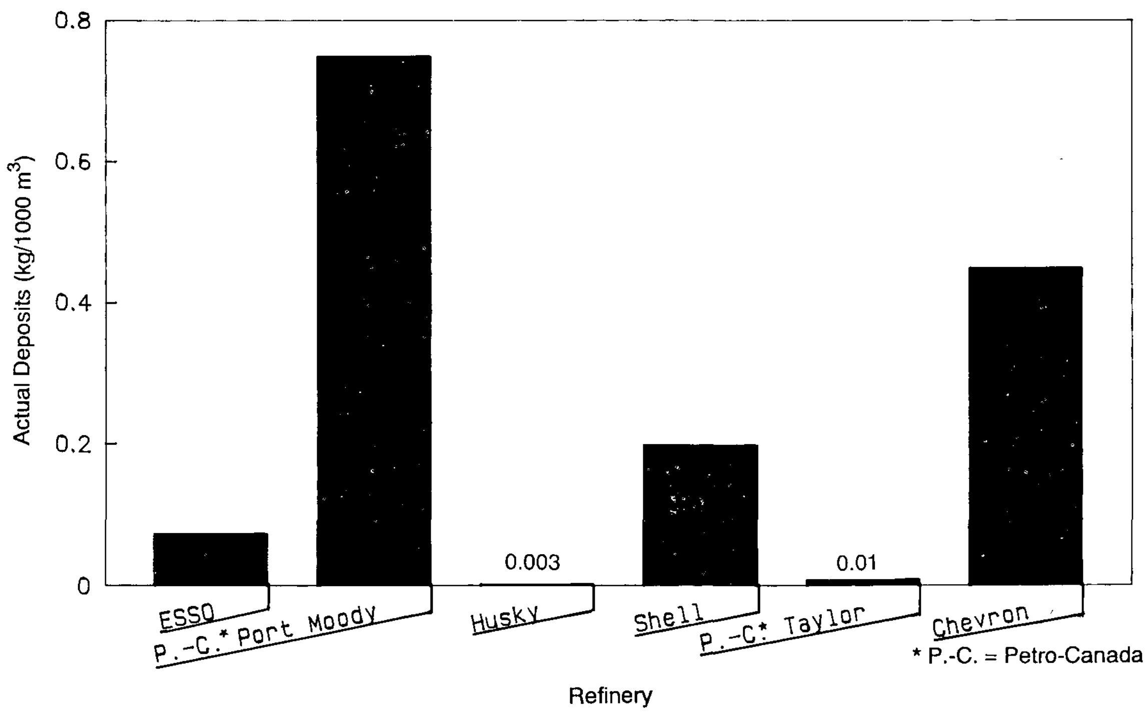


FIGURE 58 PHENOLS DISCHARGE LEVELS BY REFINERY (Pacific & Yukon Region - 1987)

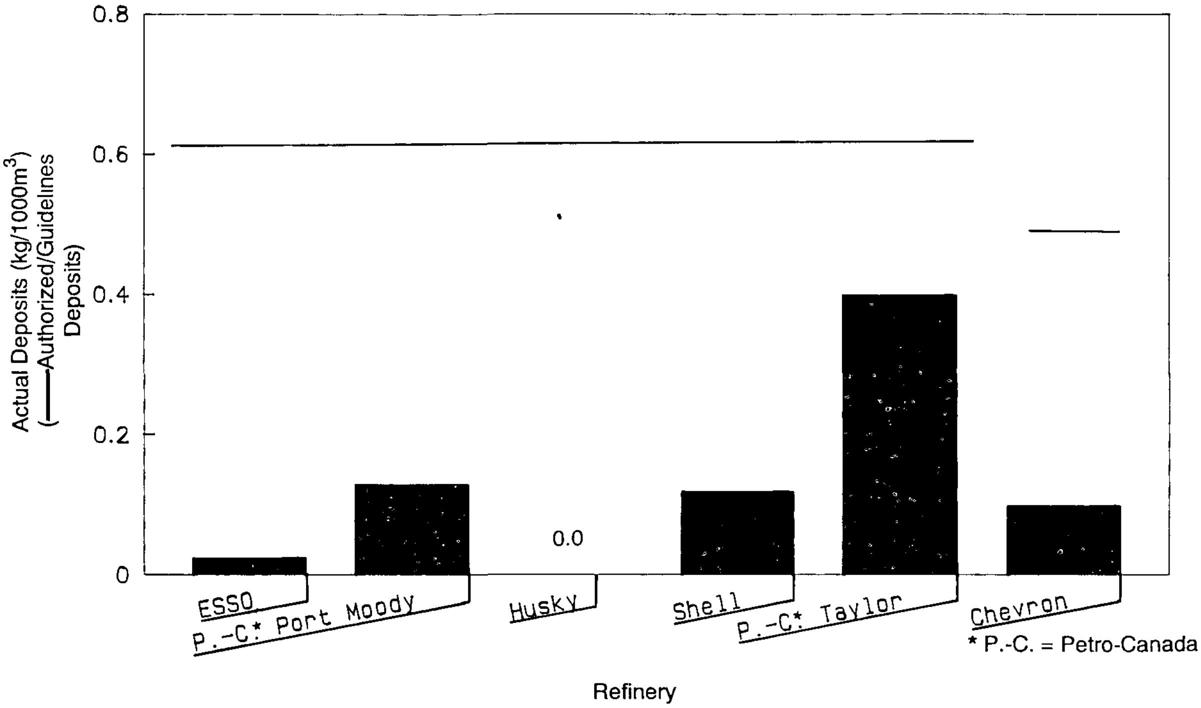


FIGURE 59 SULPHIDE DISCHARGE LEVELS BY REFINERY (Pacific & Yukon Region - 1987)

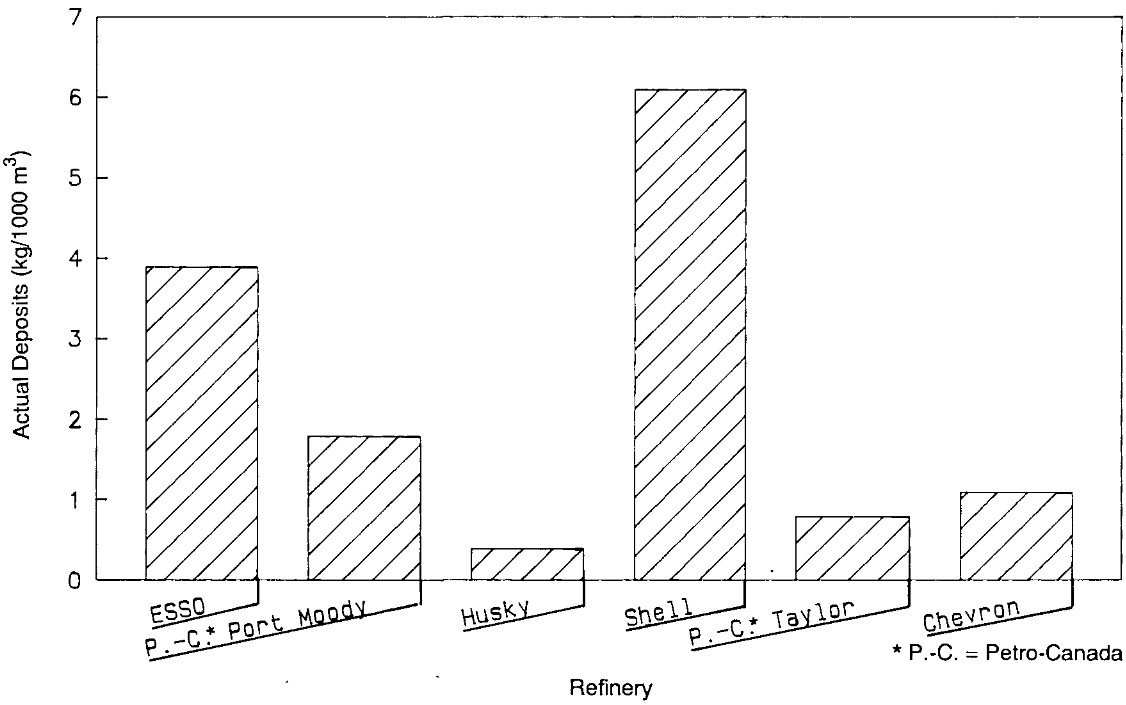


FIGURE 60 AMMONIA NITROGEN DISCHARGE LEVELS BY REFINERY (Pacific & Yukon Region - 1987)

discharge level and Petro-Canada, Taylor, had the lowest. Phenols discharge levels of three refineries (Esso, Husky and Petro-Canada, Taylor) were very low; Petro-Canada, Port Moody had the highest level in the region. The sulphide discharge levels of five refineries were very low; Petro-Canada,Taylor, had a level of discharge that was three times higher than Petro-Canada, Port Moody, which had the second highest level. The highest level of ammonia nitrogen was discharged by Shell, while Husky had the lowest level.

As a result of different provincial reporting requirements, not one refinery submitted data as often as specified in the guidelines. On average, the refineries reported only 24.5% of the tests requested in 1987 (the range was from 21% to 27%). In assessing the refineries' performance, therefore, the percentage of time that each refinery was in compliance is a better indicator than the actual number of deposits that were above the limits. Annual production was reduced in 1987 by 7% compared to 1983. This reduction was partly caused by the closure of Gulf, Kamloops in 1984. The performance of each refinery in this region is presented in Table 19 giving the 1987 value for each parameter.

TABLE 19 REFINERY FREQUENCY OF NON-COMPLIANCE WITH THE REGULATED PARAMETERS (Pacific & Yukon Region -1987)

	% of time not in compliance																			
	Oil and Grease				Total Suspended Solids				Phenols				Sulphide			Ammonia Nitrogen			pH	Toxicity
Refinery	M	O	N	S	M	O	N	S	M	O	N	S	M	O	N	M	O	N	N	N
Esso Petroleum (Ioco)	0	0	0	67	0	0	0	75	0	0	0	0	0	0	0	0	0	0	32.6	0
Petro-Canada (Port Moody)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Husky (Prince George)	0	0	0	-	0	0	0	-	0	0	0	-	0	0	0	0	0	0	8.3	0
Petro-Canada (Taylor)	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	2.1	0
Shell (Burnaby)	25	0	0	10	8.3	0	0	10	0	0	0	0	0	0	0	16.7	0	2.1	0	0
Chevron (North Burnaby)	0	0	4.3	8	25	2.1	2.1	0	8.3	0	2.2	0	0	0	0	0	0	0	11.1	100

M - monthly amount; O - one-day amount; N - maximum daily amount; S - stormwater limit

Esso Petroleum—Ioco. This Esso Petroleum refinery treats its process effluent with an oil/water separator and a biological treatment system. The effluent is discharged into Burrard Inlet. Some stormwater is segregated from process water and treated separately. The refinery is subject to the guidelines.

In 1987, Esso's process water was in compliance for all the parameters except pH. Esso's major problem was associated with stormwater. Oil and grease, and total suspended solids deposits in stormwater exceeded the limits 67% and 75% of the time, respectively. Fifty-three percent of these high deposits were less than 25% above the stormwater limits, and the rest were between 25 and 200% above the limits. Excessive stormwater discharges have been an ongoing problem.

Environmental Protection personnel conducted a wastewater audit at the refinery on November 5, 1987. Process effluent complied to the limits except for phenols.

The overall performance in 1987 was 100% in compliance with the monthly and the one-day amounts; 94% of the time in compliance with the maximum daily amounts; and only 53% of the time in compliance with the stormwater limits. Most of the annual averages for deposits were very low compared to the limits for process water. The annual deposits in stormwater, however, were above the limits for oil and grease, and total suspended solids. The refinery reported only 24% of the tests requested.

Substantial upgrading of the wastewater treatment facilities was conducted in 1984 and 1985, primarily addressing problems with oil and grease, total suspended solids and toxicity. Esso's efforts to reduce oil and grease, and total suspended solids since 1984 have improved stormwater loads somewhat, although average deposits continued to exceed the limits and total suspended solids deposits increased this year. Esso has designed and committed itself to a facility upgrading plan to be implemented in 1988.

Petro-Canada--Port Moody. The Petro-Canada refinery in Port Moody segregates its stormwater from process wastewater and treats each separately with a primary treatment system. The process effluent is forwarded to the Greater Vancouver Regional District (GVRD) sewer, while stormwater is discharged into Burrard Inlet. The refinery is subject to the guidelines.

Petro-Canada had an excellent performance in 1987 since both process and stormwaters were in full compliance with all the limits at the refinery fence. However, only 27% of the requested tests were reported.

All of the annual deposits in process water increased from the 1983 level, but were still below the limits. The annual deposits in stormwater also increased but were, again, below the limits. Increases in contaminant deposits per crude throughput may be attributed, in part, to the significant reduction in crude charges and the processing of a more sour crude.

Environment Canada conducted a wastewater audit on December 30, 1987. All parameters were in compliance with the guideline requirements.

Husky—Prince George. Husky treats its effluent (stormwater is combined) with a secondary treatment system (activated sludge) before sending it to a local pulp mill for biological treatment. The effluent "at the refinery fence" is subject to the guidelines.

In 1987, Husky was in compliance for all parameters except pH. The effluent failed to pass the pH test 8% of the time. In 1985, Husky commissioned a sour water stripper to be located at the crude unit. In 1986, the refinery divided its aeration lagoon into biox and settling zones. It has improved the effluent quality further, although four pH excursions occurred due to temporary system upsets.

The 1987 performance improved from 1983. Annual deposits of oil and grease and ammonia nitrogen were reduced. Discharge level for total suspended solids increased and the other two parameters stayed approximately at the same level. The annual deposits were all below the limits. Husky reported only 23% of the tests required.

Petro-Canada—Taylor. This Petro-Canada refinery is associated with a gas plant, sulphur plant and natural gas liquids plant. The combined effluent is treated in an activated sludge system and discharged into the Peace River. Stormwater from the complex is segregated from process effluent and treated in a primary system before being discharged into the same river. The combined (refinery and other plants) effluent was assessed against the guidelines limits.

During 1987, Petro-Canada's process water was in full compliance for all parameters except pH. The pH levels were exceeded 7% of the time. In addition, total suspended solids exceeded the stormwater limits once. This single high excursion was caused by the background solids washed away by heavy rainfall.

All the annual deposits were below the limits, although sulphide was close to the limit. Most of the deposits were reduced or equal to the 1983 levels. Total suspended solids is the only parameter that increased when compared to 1983. The refinery reported only 27% of the requested tests. Overall, Petro-Canada had a better performance in 1987.

Shell—Burnaby. This Shell refinery has an intermediate treatment system (air flotation unit) and discharges its effluent to the Greater Vancouver Regional District GVRD sewer. Stormwater is treated separately at the refinery and discharged into Burrard Inlet. The refinery is subject to the guidelines.

Environment Canada conducted an audit on December 4, 1987. Process effluent samples were taken prior to discharge to GVRD sewer. All parameters were in compliance with the guidelines.

In 1987, process effluent deposits were in compliance with phenols, sulphide, pH, and toxicity. The oil and grease, total suspended solids and ammonia nitrogen deposits exceeded mainly the monthly amounts with the exception of one maximum daily limit excursion for ammonia nitrogen. Stormwater deposits were also in compliance with the exception of one oil and grease, and one total suspended solid excursion. Overall, the refinery was in compliance with the monthly amounts 90% of the time, the one-day amounts 100% of the time, the maximum daily amounts 99.7% of the time and 93% of the time in compliance with the stormwater limits. The company reported only 25% of the tests requested. All of the annual deposits for the process effluent increased over the 1983 levels, but stayed below the limits.

Chevron—North Burnaby. Chevron is the only refinery in the region with an expanded status under the guidelines. The refinery uses two segregated wastewater treatment systems for process and storm waters. The process wastewater treatment system includes an air flotation unit (intermediate system) and the effluent is discharged into the GVRD sewer. Stormwater undergoes a similar treatment but is discharged into Burrard Inlet.

On December 19, 1987, Environment Canada conducted a wastewater audit on effluent discharged to Burrard Inlet from the refinery. The samples complied with all requirements except oil and grease in the stormwater. Fish bioassay test indicated 50% mortality for the 96-h LC_{50}.

In 1987, Chevron was in compliance with the monthly amounts 90% of the time, 99.5% of the time with one-day amounts, 96% of the time with maximum daily and 97% of the time with the stormwater limits. All of the monthly exceedences were due to total suspended solids and phenols. Most of the 1987 deposits were reduced from 1983, however total suspended solids have increased by 44% and sulphide deposits are five times higher. All of the annual deposits were below the limits. Chevron reported only 21% of the tests requested and performed only one toxicity test.

4 CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations which follow are based on an assessment of: information collected through industry surveys performed by the Petroleum Association for Conservation of the Canadian Environment (PACE) and Environment Canada, or through federal regulatory and guideline requirements; explanations reported by the oil refineries on problems encountered in operating their wastewater treatment systems; environmental studies conducted for PACE and Environment Canada over the past few years; and current pollution abatement technologies. No detailed feasibility studies were made and no consideration was given to economic and legislative limitations nor local requirements. Given these restrictions, the following conclusions and recommendations can be drawn from the study.

4.1 Conclusions

1) In general, the refineries continue to improve their effluent qualities from year to year although some refineries still exceed the regulations and guidelines limits for certain parameters.

2) New refineries benefit from the most up-to-date wastewater treatment technology and generally have better performance than the older refineries.

3) Since 1972, there has been a general downward trend for the net discharges of all the parameters. If the 1987 discharges are compared to the 1983 levels, reductions ranging from 21% to 67% are found for all parameters.

4) Most of the refineries have a secondary treatment system or send their effluents off-site for further treatment.

5) Under good operating conditions, the wastewater treatment systems existing at the refineries should easily meet the limits prescribed in the federal regulations and guidelines, and attain levels that are well below the limits.

6) Generally, the regulations and guideline limits are exceeded when the wastewater treatment system is upset (overloaded), or has mechanical deficiencies. More than 38% of the monthly excursions or violations occurred for total suspended solids.

7) Under good operating conditions, the best practicable wastewater treatment technology (used in most refineries) is very efficient in removing or sometimes eliminating organic priority pollutants from waste streams, while most metals accumulate in the sludges.

4.2 Recommendations

1) The refineries should report <u>all</u> tests required by the federal regulations and guidelines. It should be noted that even though the provincial reporting

requirements may be different from the federal requirements, both must be reported to the provincial government.

2) The refineries should also declare a revised reference crude rate when the arithmetic mean of the stream day crude rates during two consecutive months is less than 85% of the last RCR declared.

3) Wastewater treatment systems should be kept in good operating condition and optimized to remove traditional and organic priority pollutants (which are normally reduced with the traditional ones). To achieve this goal, it is suggested that training (or refresher) courses be provided to operators of the wastewater treatment system and that operating conditions be defined to optimize removal of biodegradable priority pollutant compounds.

4) The federal refinery effluent regulations and guidelines should be reviewed and updated to reflect changes in the industry, current analytical methodology, and changes in focus towards toxic chemicals.

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APPENDIX A

COMPARISONS OF PROVINCIAL AND FEDERAL LIMITS FOR COMMON POLLUTANTS IN REFINERY WASTEWATERS

TABLE A-1 COMPARISON OF FEDERAL AND PROVINCIAL LIMITS FOR REFINERY WASTEWATER

Parameter: Oil & Grease

Region	Status	Maximum Deposits ($lb/10^3\ bbl \cdot d^{-1}$ of crude oil) Daily Average	Monthly Average	One Day a Month	Maximum Daily	Maximum Concentration (mg/L)
Canada	- new refinery					
	- existing refinery that is altered or expanded		3.0	5.5	7.5	
	- existing refinery, unaltered portion		6.0	11.0	15.0	
Quebec	- new		3.09	5.51	7.50	
	- existing		6.17	11.0	15.0	
Ontario	- all					10
Alberta	- with disposal wells		2.0	3.7	5.0	10
	- without disposal wells		3.0	5.5	7.5	10
British Columbia	- discharge to marine water:					
	Level A	1.15*				
	Level B	2.80**				
	Level C					15**
	- discharge to freshwater:					
	Level A	0.58*				
	Level B	2.80**				
	Level C					15**

* total oil
** nonvolatile oil

TABLE A-2 COMPARISON OF FEDERAL AND PROVINCIAL LIMITS FOR REFINERY WASTEWATER

Parameter: Total Suspended Matter

Region	Status	Maximum Deposits ($lb/10^3\ bbl \cdot d^{-1}$ of crude oil) Daily Average	Monthly Average	One Day a Month	Maximum Daily	Maximum Concentration (mg/L)
Canada	- new refinery					
	- existing refinery that is altered or expanded		7.2	12.0	15.0	
	- existing refinery, unaltered portion		14.4	24.0	30.0	
Quebec	- new		7.19	12.0	15.0	
	- existing		14.4	24.0	30.0	
Ontario	- all					15
Alberta	- with disposal wells		4.8	8.0	10.0	25
	- without disposal wells		7.2	12.0	15.0	25
British Columbia	- discharge to marine water:					
	Level A	20				
	Level B	20				
	Level C	30				
	- discharge to freshwater:					
	Level A	20				
	Level B	20				
	Level C	30				

TABLE A-3 COMPARISON OF FEDERAL AND PROVINCIAL LIMITS FOR REFINERY WASTEWATER

Parameter: Phenols

Region	Status	Maximum Deposits ($lb/10^3\ bbl \cdot d^{-1}$ of crude oil) Daily Average	Monthly Average	One Day a Month	Maximum Daily	Maximum Concentration (mg/L)
Canada	- new refinery					
	- existing refinery that is altered or expanded		0.3	0.55	0.75	
	- existing refinery, unaltered portion		0.6	1.1	1.5	
Quebec	- new		0.31	0.55	0.75	
	- existing		0.62	1.10	1.50	
Ontario	- all					0.02
Alberta	- with disposal wells		0.2	0.37	0.50	1.0
	- without disposal wells		0.3	0.55	0.75	1.0
British Columbia	- discharge to marine water:					
	Level A	0.023				
	Level B	0.06				
	Level C	0.2				
	- discharge to freshwater:					
	Level A	0.023				
	Level B	0.06				
	Level C	0.2				

TABLE A-4 COMPARISON OF FEDERAL AND PROVINCIAL LIMITS FOR REFINERY WASTEWATER

Parameter: Ammonia Nitrogen

Region	Status	Maximum Deposits ($lb/10^3\ bbl \cdot d^{-1}$ of crude oil) Daily Average	Monthly Average	One Day a Month	Maximum Daily	Maximum Concentration (mg/L)
Canada	- new refinery					
	- existing refinery that is altered or expanded		3.6	5.7	7.2	
	- existing refinery, unaltered portion		5.0	8.0	10.0	
Quebec	- new		3.59	5.73	7.21	
	- existing		4.98	7.98	9.96	
Ontario	- all					10
Alberta	- with disposal wells		2.4	3.9	4.8	12.5
	- without disposal wells		3.6	5.7	7.2	12.5
British Columbia	- discharge to marine water:					
	Level A	0.576				
	Level B	1.87				
	Level C					15
	- discharge to freshwater*:					
	Level A	0.576				
	Level B	1.87				
	Level C					15

* as ammonia

TABLE A-5 COMPARISON OF FEDERAL AND PROVINCIAL LIMITS FOR REFINERY WASTEWATER

Parameter: Sulphide

Region	Status	Maximum Deposits (lb/10^3 bbl·d^{-1} of crude oil)				Maximum Concentration (mg/L)
		Daily Average	Monthly Average	One Day a Month	Maximum Daily	
Canada	- new refinery					
	- existing refinery that is altered or expanded		0.1	0.3	0.5	
	- existing refinery, unaltered portion		0.2	0.6	1.0	
Quebec	- new		0.11	0.31	0.51	
	- existing		0.22	0.62	1.01	
Alberta	- with disposal wells		0.065	0.20	0.33	0.35
	- without disposal wells		0.1	0.30	0.50	0.35
British Columbia	- discharge to marine water*:					
	Level A	0.011				
	Level B	0.02				
	Level C					1.0
	- discharge to freshwater:					
	Level A	0.011				
	Level B	0.02				
	Level C					1.0

* sulphides and mercaptans as sulphur

TABLE A-6 COMPARISON OF FEDERAL AND PROVINCIAL LIMITS FOR REFINERY WASTEWATER

Parameter: pH

Region	Status	Maximum Range	
		Maximum Daily	Continuous
Canada	- new refinery		
	- existing refinery that is altered or expanded	6.0 to 9.5	
	- existing refinery, unaltered portion	6.0 to 9.5	
Quebec	- new	6.0 to 9.5	
	- existing	6.0 to 9.5	
Ontario	- all		5.5 to 9.5
Alberta	- with disposal wells	6.0 to 9.5	
	- without disposal wells	6.0 to 9.5	
British Columbia	- discharge to marine water:		
	Level A		6.5 to 8.5
	Level B		6.5 to 9.0
	Level C		6.5 to 9.0
	- discharge to freshwater:		
	Level A		6.5 to 8.5
	Level B		6.5 to 8.5
	Level C		6.5 to 9.0

TABLE A-7 COMPARISON OF FEDERAL AND PROVINCIAL LIMITS FOR REFINERY STORMWATER

Region***	Status	Oil & Grease Deposits		Phenol Deposits		Total Suspended Matter	
		Conc.*	Limit**	Conc.*	Limit**	Conc.*	Limit**
Canada	- new refinery						
	- existing refinery that is altered or expanded	1.0	25.0	0.1	2.5	3.0	75.0
	- existing refinery, unaltered portion	1.0	50.0	0.1	5.0	3.0	150.0
Quebec	- all	1.0	25.0	0.1	2.5	3.0	75.0
Alberta	- all	1.0	20.0	0.1	2.0	3.0	60.0

* lbs/10^4 Canadian gal. of stormwater
** lbs/10^3 bbl of crude$\cdot d^{-1}$
*** in British Columbia and Ontario, the limits on concentration in waste discharges will control discharge of contaminated stormwater

APPENDIX B

COMPLIANCE ASSESSMENT: ACTUAL AND AUTHORIZED DEPOSITS FOR 1987 ON A NATIONAL, A REGIONAL, AND AN INDIVIDUAL REFINERY BASIS

TABLE B-1 DEPOSITS AND COMPLIANCE ASSESSMENT (National 1987)

	Region					
	Atlantic		Quebec		Ontario	
A. DEPOSITS						
Yearly Average of Daily Deposits (kg/10^3 m^3 of crude oil)	Authorized Deposits	Actual Deposit	Authorized Deposits	Actual Deposits	Authorized Deposits	Actual Deposits
Oil and Grease	16.6	6.5	17.1	9.1	14.1 (3.1)**	2.2 (0.4)
Total Suspended Solids	40.0	24.7	41.1	36.4	33.8 (9.2)	7.4 (1.0)
Phenols	1.7	0.4	1.7	0.33	1.4 (0.3)	0.01 (0.003)
Sulphide	0.6	0.1	0.6	0.28	0.5	-0.17
Ammonia Nitrogen	14.1	3.1	14.3	4.68	12.9	1.4

B. COMPLIANCE ASSESSMENT

a) Number of Deposits in Excess of Limits Set in Guidelines or Regulations*

	Atlantic M	Atlantic O	Atlantic N	Quebec M	Quebec O	Quebec N	Ontario M	Ontario O	Ontario N	Ontario S
Oil and Grease	0	0	0	3	3	3	1	2	5	1
Total Suspended Solids	3	5	15	8	24	20	7	14	22	0
Phenols	1	1	5	1	1	4	0	0	0	0
Sulphide	2	6	1	2	1	3	1	0	1	
Ammonia Nitrogen	0	0	1	2	14	15	1	8	13	
pH			1			10			0	
Toxicity			4			1			0	
Total	6	12	27	16	43	56	10	24	41	1
Percentage of National	7	13	15	20	44	32	12	25	23	5
Percentage of Time not in Compliance	3.2	0.4	0.6	8.9	1.9	1.6	4.9	0.3	0.4	1.4

b) Number of Monthly Amounts and Stormwater Deposits Exceeding the Limits by:

	Atlantic	Quebec	Ontario
0 to 24%	3	7	2
25 to 49%	0	5	4
50 to 99%	2	2	3
100 to 199%	1	1	2
+200%	0	1	0

* M: Monthly amount; O: One-day amount; N: Maximum daily amount; S: Stormwater monthly amount.

** Deposits in brackets are for stormwater (annual average).

	Region		
	Atlantic	Quebec	Ontario
Reference Crude Rate ($10^3 m^3/d$)	40.75	43.84	77.28
Status	existing 33.81 + new 6.94	existing	existing 49.83 + expanded 3.26 + new 24.19
Percentage of Tests Reported	97.1	98.5	84.7

Western & Northern		Pacific & Yukon		National	
Authorized Deposits	Actual Deposits	Authorized Deposits	Actual Deposits	Authorized Deposits	Actual Deposits
11.5 (2.4)	2.23 (0.07)	16.5 (4.56)	4.4 (2.31)	14.43 (3.73)	4.35 (0.55)
27.4 (7.1)	7.9 (1.01)	39.3 (13.2)	15.6 (9.9)	34.6 (11.19)	16.3 (2.29)
1.2 (0.24)	0.6 (0.004)	1.6 (0.46)	0.33 (0.10)	1.45 (0.38)	0.31 (0.02)
0.4	0.03	0.57	0.11	0.51	0.03
11.6	3.7	14.0	2.4	13.04	2.93

M	O	N	S	M	O	N	S	M	O	N	S
6	3	5	0	3	0	2	10	13	8	15	11
8	13	16	0	5	1	1	11	31	57	74	11
13	0	0	0	1	0	1	0	16	2	10	0
1	0	0		0	0	0		6	7	5	
12	0	0		2	0	1		17	22	30	
		0				24				35	
		0				1				6	
40	17	21	0	11	1	30	21	83	96	175	22
48	17	12	0	13	1	17	95				
11.8	1.4	1	0	3.2	0.1	1.8	13.9	5.7	0.6	0.8	8.4

3	16	31
6	8	23
5	6	18
14	1	19
12	1	14

Western & Northern	Pacific & Yukon	National
62.26	23.63	247.76
existing 20.96 + expanded 3.09 + new 38.21	existing 21.57 + expanded 2.06	existing 170.01 + expanded 8.41 + new 69.34
34.1	24.5	62.2

TABLE B-2 DEPOSITS AND COMPLIANCE ASSESSMENT (Atlantic Region - 1987)

		Refinery					
		Esso Petroleum Dartmouth			Irving St. John		
A. DEPOSITS							
Yearly Average of Daily Deposits (kg/$10^3 m^3$ of crude oil)	Guideline Deposits (Esso, Irving, Texaco)	Actual Deposits			Actual Deposits		
Oil and Grease	17.1	6.48 ± 51%**			7.74 ± 39%		
Total Suspended Solids	41.1	34.1 ± 47%			22.3 ± 27%		
Phenols	1.7	0.74 ± 103%			0.17 ± 41%		
Sulphide	0.6	0 ± 0%			0.12 ± 42%		
Ammonia Nitrogen	14.3	2.26 ± 22%			3.72 ± 44%		
B. COMPLIANCE ASSESSMENT							
a) Number of Deposits in Excess of Limits Set in Guidelines*		M	O	N	M	O	N
Oil and Grease		0	0	0	0	0	0
Total Suspended Solids		2	0	7	0	0	0
Phenols		1	1	5	0	0	0
Sulphide		0	0	0	0	0	0
Ammonia Nitrogen		0	0	0	0	0	0
pH				0			0
Toxicity				1			3
Total		3	1	13	0	0	3
Percentage of Region		50	8	48	0	0	11
Percentage of Time not in Compliance		5.0	0.1	1.1	0	0	0.3
b) Number of Monthly Amounts Exceeding the Limits by:							
0 to 24%			1			0	
25 to 49%			0			0	
50 to 99%			2			0	
100 to 199%			0			0	
+200			0			0	

* M: Monthly amount; o: One-day amount; N: Maximum daily amount.
** Standard deviation expressed in percent.

	Refinery	
	Esso Petroleum Dartmouth	Irving St. John
Reference Crude Rate (10^3 m^3/d)	11.6	18.81
Status	Existing	Existing
Number of Months in Operation	12	12
Number of Tests Reported	1160	1156

Texaco Dartmouth		Newfoundland Energy Ltd. Come-by Chance			Region	
Actual Deposits		Authorized Deposits	Actual Deposits		Authorized Deposits	Actual
1.71	± 47%	8.6	2.58	± 28%	16.6	6.5
9.45	± 69%	20.5	17.92	± 33%	40.0	24.7
0.31	± 55%	0.9	0.11	± 27%	1.7	0.4
0	± 0%	0.3	0.51	± 49%	0.6	0.1
2.2	± 142%	10.3	4.5	± 18%	14.1	3.1

M	O	N	M	O	N	M	O	N
0	0	0	0	0	0	0	0	0
0	0	2	1	5	6	3	5	15
0	0	0	0	0	0	1	1	5
0	0	0	2	6	1	2	6	1
0	0	0	0	0	1	0	0	1
		1			NR			1
		0			NR			4
0	0	3	3	11	8	6	12	27
0	0	11	50	92	30			
0	0	0.2	30	5.7	4.1	3.2	0.4	0.6
	0			2			3	
	0			0			0	
	0			0			2	
	0			1			1	
	0			0			0	

Texaco Dartmouth	Newfoundland Energy Ltd. Come-by Chance	Region
3.4	11.9	40.75
Existing	New	Existing 33.81 + New 6.94
12	7	
1687	198	4201

TABLE B-3 DEPOSITS AND COMPLIANCE ASSESSMENT (Quebec Region - 1987)

		Refinery
		Petro-Canada*** Pointe-aux-Trembles
A. DEPOSITS		
Yearly Average of Daily Deposits ($kg/10^3\ m^3$ of crude oil)	Guideline Deposits	Actual Deposits
Oil and Grease	17.1	14.59 ± 20%**
Total Suspended Solids	41.1	29.39 ± 15%
Phenols	1.7	0.47 ± 38%
Sulphide	0.6	0.09 ± 67%
Ammonia Nitrogen	14.3	9.9 ± 70%

B. COMPLIANCE ASSESSMENT

a) Number of Deposits in Excess of Limits Set in Guidelines*	M	O	N
Oil and Grease	2	3	0
Total Suspended Solids	0	0	0
Phenols	0	0	0
Sulphide	0	0	0
Ammonia Nitrogen	2	12	12
pH			0
Toxicity			1
Total	4	15	13
Percentage of Region	25	35	23
Percentage of Time not in Compliance	6.7	2	1.1

b) Number of Monthly Amounts Exceeding the Limits by:	
0 to 24%	3
25 to 49%	0
50 to 99%	0
100 to 199%	1
+200	0

* M: Monthly amount; O: One-day amount; N: Maximum daily amount.
** Standard deviation expressed in percent.
*** Combined petrochemical and refinery effluent.

	Refinery
	Petro-Canada Pointe-aux-Trembles
Reference Crude Rate ($10^3\ m^3/d$)	12.0
Status	Existing
Number of Months in Operation	12
Number of Tests Reported	1142

Shell*** Montreal		Ultramar St. Romuald		Region
Actual Deposits		Actual Deposits		Actual Deposits
10.94 ±	37%	2.23 ±	49%	9.1
50.16 ±	31%	25.6 ±	24%	36.4
0.18 ±	122%	0.38 ±	163%	0.33
0.12 ±	183%	0.63 ±	340%	0.28
3.74 ±	89%	1.46 ±	52%	4.68

M	O	N	M	O	N	M	O	N
1	0	3	0	0	0	3	3	3
8	23	17	0	1	3	8	24	20
0	0	1	1	1	3	1	1	4
1	1	2	1	0	1	2	1	3
0	2	3	0	0	0	2	14	15
		1			9			10
		0			0			1
10	26	27	2	2	16	16	43	56
62	60	48	13	5	29			
16.7	3.4	2.4	3.3	0.3	1.4	8.9	1.9	1.6
	4			0			7	
	4			1			5	
	2			0			2	
	0			0			1	
	0			1			1	

Shell Montreal	Ultramar St. Romuald	Region
17.45	14.39	43.84
Existing	Existing	Existing
12	12	
1145	1132	3419

TABLE B-4 DEPOSITS AND COMPLIANCE ASSESSMENT (Ontario Region - 1987)

		Refinery				
		Esso[e] Sarnia	Shell Corunna	Petro-Canada[a] Clarskon	Petro-Canada Trafalgar	
A. DEPOSITS						
Yearly Average of Daily Deposits ($kg/10^3\ m^3$ of crude oil)	Guideline Deposits (Esso, Shell, Petro-Canada, Clarkson)	Actual Deposits	Actual Deposits	Actual Deposits	Guideline Deposits	Actual Deposits
Oil and Grease	17.1 (4.76)[d]	0.64 ± 53%**	4.5 ± 159%	5.2 ± 52% (1.19 ± 160%)	15.8	1.43 ± 38%
Total Suspended Solids	41.1 (14.3)	4.3 ± 114%	5.9 ± 1800%	17.6 ± 40% (2.52 ± 166%)	37.9	15.0 ± 37%
Phenols	1.7 (0.48)	0.03 ± 100%	0.002 ± 1198%	0.007 ± 74% (0.01 ± 115%)	1.6	0.02 ± 35%
Sulphide	0.6	0.02 ± 300%	-1.5[c] ± 321%	0.04 ± 87%	0.55	0.4 ± 40%
Ammonia Nitrogen	14.3	1.29 ± 79%	-1.5[c] ± 235%	3.0 ± 110%	13.6	3.1 ± 64%

B. COMPLIANCE ASSESSMENT

	Esso Sarnia			Shell Corunna			Petro-Canada Clarkson				Petro-Canada Trafalgar		
a) Number of Deposits in Excess of Limits Set in Guidelines*	M	O	N	M	O	N	M	O	N	S	M	O	N
Oil and Grease	0	0	0	1	1	4	0	0	1	1	0	0	0
Total Suspended Solids	0	0	0	6	8	14	0	4	5	0	0	0	0
Phenols	0	0	0	0	0	0	0	0	0	0	0	0	0
Sulphide	0	0	0	0	0	1	0	0	0		1	0	0
Ammonia Nitrogen	0	0	0	0	0	0	0	6	9		0	0	0
pH			0			0			0				0
Toxicity			0			0			0				0
Total	0	0	0	7	9	19	0	10	15	1	1	0	0
Percentage of Region	0	0	0	70	37	46	0	42	37	100	10	0	0
Percentage of Time not in Compliance	0	0	0	11.9	1.4	2.2	0	0.6	0.7	2.8	1.7	0	0
b) Number of Monthly Amounts Exceeding the Limits by:													
0 to 24%		0			0			1				0	
25 to 49%		0			3			0				0	
50 to 99%		0			2			0				1	
100 to 199%		0			2			0				0	
+200		0			0			0				0	

a) A limited number of cooling-water analyses (usually 4 to 5/month for each cooling water trap outfall) are conducted for oil and grease and phenols. Cooling water, suspended solids, sulphide, and ammonia nitrogen are not monitored. Yearly average loadings may be higher than indicated.
b) Petrosar did not report the level of sulphide according to an agreement with Ontario MOE.
c) See discussion of the individual refineries for explanation of the negative values.
d) Deposits in bracket are for stormwater (annual - average).
e) Combined refinery and petrochemical effluents.

* M: Monthly amount; O: One-day amount; N: Maximum daily amount; S: Stormwater monthly amount.
** Standard deviation expressed in percent.
NR - Not Reported.

	Refinery			
	Esso Sarnia	Shell Corunna	Petro-Canada Clarkson	Petro-Canada Trafalgar
Reference Crude Rate ($10^3\ m^3/d$)	18.34	11.21	6.64	7.95
Status	Existing	Existing	Existing	Existing 6.71 + Expanded 1.24
Number of Months in Operation	12	12	12	12
Number of Tests Reported	948	866	2190	1260

Suncor Sarnia			Petrosar[b,e] Corunna	Texaco Nanticoke	Region	
Guideline Deposits	Actual Deposits	Authorized Deposits (Petrosar, Texaco)	Actual Deposits	Actual Deposits	Authorized Deposits	Actual Deposits
15.2	6.1 ± 61%	8.6 (2.4)	0.29 ± 72%	0.37 ± 84% (0.06 ± 90%)	14.1 (3.1)	2.2 (0.4)
36.5	23.0 ± 44%	20.5 (7.1)	2.5 ± 93%	-2.3 ± 193% (0.4 ± 88%)	33.8 (9.2)	7.4 (1.0)
1.5	0.02 ± 86%	0.9 (0.2)	0.004 ± 25%	0 ± 0% (0 ± 0%)	1.4 (0.3)	0.01 (0.003)
0.53	0.02 ± 191%	0.3	NR	-0.001 ± 982%	0.5	-0.17
13.4	4.5 ± 102%	10.3	1.6 ± 54%	0.03 ± 180%	12.9	1.4

M	O	N	M	O	N	M	O	N	S	M	O	N	S
0	1	0	0	0	0	0	0	0	0	1	2	5	1
1	2	3	0	0	0	0	0	0	0	7	14	22	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	NR	NR	NR	0	0	0		1	0	1	
1	2	4	0	0	0	0	0	0		1	8	13	
		0			0			0				0	
		0			0			0				0	
2	5	7	0	0	0	0	0	0	0	10	24	41	1
20	21	17	0	0	0	0	0	0	0				
3.3	0.7	0.7	0	0	0	0	0	0	0	2.5	0.3	0.4	1.4
	1				0			0			2		
	1				0			0			4		
	0				0			0			3		
	0				0			0			2		
	0				0			0			0		

Suncor Sarnia	Petrosar Corunna	Texaco Nanticoke	Region
8.95	8.29	15.9	77.28
Existing 6.93 + Expanded 2.02	New	New	Existing 49.83 + Expanded 3.26 + New 24.19
12	12	12	
958	1830	1478	9530

TABLE B-5 DEPOSITS AND COMPLIANCE ASSESSMENT (Western & Northern Region - 1987)

		Refinery					
		Petro-Canada(a,b) Moose Jaw	Shell Bowden	Petro-Canada Edmonton		Co-op(a,b) Regina	
A. DEPOSITS							
Yearly Average of Daily Deposits (kg/10^3 m^3 crude oil)	Guideline Deposits (Petro-Canada, Moose Jaw; Shell-Bowden)	Actual Deposits	Actual Deposits	Guideline Deposits	Actual Deposits	Guideline Deposits	Actual Deposits
Oil and Grease	17.1	2.48 ± 119%***		16.6	0.75 ± 39%	14.3	2.46 ± 39%
Total Suspended Solids	41.1	5.29 ± 58%	No discharge	39.8	6.77 ± 52%	34.4	12.67 ± 35%
Phenols	1.7	0.9 ± 70%		1.65	0.013 ± 85%	1.4	4.85 ± 33%
Sulphide	0.6	0.16 ± 188%		0.6	0	0.5	0:09 ± 119%
Ammonia Nitrogen	14.3	0.68 ± 77%		14.05	0.3 ± 38%	13	29.5 ± 27%

B. COMPLIANCE ASSESSMENT

a) Number of Deposits in Excess of Limits Set in Guidelines*	Petro-Canada Moose Jaw M	O	N	Shell Bowden M	O	N	Petro-Canada Edmonton M	O	N	Co-op Regina M	O	N
Oil and Grease	0	NR	NR**				0	0	0	0	NR	NR
Total Suspended Solids	0	NR	NR				0	0	0	0	NR	NR
Phenols	1	NR	NR				0	0	0	12	NR	NR
Sulphide	1	NR	NR				0	0	0	0	NR	NR
Ammonia Nitrogen	0	NR	NR				0	0	0	12	NR	NR
pH			0						0			0
Toxicity			NR						0			NR
Total	2	-	0				0	0	0	24	-	0
Percentage of Region	5	-	-				0	0	0	60	-	0
Percentage of Time not in Compliance	5	-	-				0	0	0	40	-	0

b) Number of Monthly Amounts Exceeding the Limits by:	Petro-Canada Moose Jaw	Shell Bowden	Petro-Canada Edmonton	Co-op Regina
0 to 24%	1		0	0
25 to 49%	1		0	3
50 to 99%	0		0	2
100 to 199%	0		0	11
+200	0		0	8

a) Company reported only monthly averages thus making it impossible to assess the daily amounts.
b) Effluent receives offsite treatment at municipal facility which is considered to give equivalent treatment for all parameters except ammonia nitrogen.
c) Deposits in bracket are for stormwater (annual - average).
d) Deep-well injection of process effluent only.
* M: Monthly amount; O: One-day amount; N: Maximum daily amount; S: Stormwater monthly amount.
** NR: Not Reported.
*** Standard deviation expressed in percent.

	Refinery			
	Petro-Canada Moose Jaw	Shell Bowden	Petro-Canada Edmonton	Co-op Regina
Reference Crude Rate (10^3 m^3/d)	1.59	0.95	15.09	6.36
Status	Existing	Existing	Existing 14.15 + Expanded 0.94	Existing 4.29 + Expanded 2.07
Number of Months in Operation	8	12	12	12
Number of Tests Reported	48	-	625	243

	Esso Norman Wells			Shell Scotford	Turbo[(d)] Balzac	Husky[(d)] Lloydminster	Esso Edmonton	Region	
	Guideline Deposits	Actual Deposits	Authorized Deposits (Shell, Scotford; Turbo; Husky; Esso, Edmonton)	Actual Deposits	Actual Deposits	Actual Deposits	Actual Deposits	Authorized Deposits	Actual Deposits
	15.9	23.74 ± 95%	8.6 (2.4)[(c)]	2.28 ± 108%	(0.04 ± 104%)	(0.1)	2.59 ± 47%	11.5 (2.4)	2.23 (0.07)
	38.3	103.2 ± 116%	20.5 (7.1)	10.56 ± 73%	(1.8 ± 59%)	(0.11)	3.53 ± 49%	27.4 (7.1)	7.9 (1.01)
	1.59	0.1 ± 120%	0.9 (0.2)	0.009 ± 73%	(0.008 ± 75%)	(0)	0.006 ± 67%	1.2 (0.24)	0.6 (0.004)
	0.56	0.14 ± 93%	0.3	NR	deep-well injection of process water	deep-well injection of process water	0.027 ± 62%	0.4	0.03
	13.8	1.64 ± 71%	10.3	NR			0.28 ± 87%	11.6	3.7

	M	O	N	M	O	N	M	O	N	S	M	O	N	S	M	O	N	M	O	N	S
	6	3	5	0	0	0				0				0	0	0	0	6	3	5	0
	8	13	16	0	0	0				0				0	0	0	0	8	13	16	0
	0	0	0	0	0	0				0				0	0	0	0	13	0	0	0
	0	0	0	NR	NR	NR									0	0	0	1	0	0	
	0	0	0	NR	NR	NR									0	0	0	12	0	0	
			0			0											0			0	
			0			0											0			0	
	14	16	21	0	0	0				0				0	0	0	0	40	16	21	
	35	100	100	0	0	0				0				0	0	0	0				
	23.3	6.3	6.8	0	0	0				0				0	0	0	0	11.8	1.4		!
		2			0			0				0				0			3		
		2			0			0				0				0			6		
		3			0			0				0				0			5		
		3			0			0				0				0			14		
		4			0			0				0				0			12		

	Esso Norman Wells	Shell Scotford	Turbo Balzac	Husky Lloydminster	Esso Edmonton	Region
	0.59	9.94	3.94	3.42	20.91	62.26
	Existing 0.51 + Expanded 0.08	New	New	New	New	Existing 20.96 + Expanded 3.09 + New 38.21
	12	12	12	12	12	
	307	232	-	-	624	2079

TABLE B-6 DEPOSITS AND COMPLIANE ASSESSMENT (Pacific & Yukon Region - 1987)

		Refinery		
		Esso Ioco	Petro-Canada[b] Port Moody	Husky[b] Prince George
A. DEPOSITS				
Yearly Average of Daily Deposits ($kg/10^3\ m^3$ of crude oil)	Guideline Deposits (Esso, Petro-Canada - Port Moody Husky, Shell, Petro-Canada - Taylor)	Actual Deposits	Actual Deposits	Actual Deposits
Oil and Grease	17.1 (4.76)	1.64 ± 63%*** (5.44 ± 43%)**	4.35 ± 39% (0.35 ± 117%)	0.22 ± 37%
Total Suspended Solids	41.1 (14.3)	7.5 ± 44% (17.7 ± 26%)	14.77 ± 11% (2.87 ± 83%)	7.62 ± 63%
Phenols	1.7 (0.48)	0.07 ± 60% (0.22 ± 55%)	0.76 ± 32% (0.003 ± 100%)	0.003 ± 200%
Sulphide	0.6	0.025 ± 25%	0.13 ± 38%	0
Ammonia Nitrogen	14.3	3.81 ± 68%	1.69 ± 34%	0.38 ± 62%

B. COMPLIANCE ASSESSMENT

a) Number of Deposits in Excess of Limits Set in Guidelines*	Esso M	Esso O	Esso N	Esso S	Petro-Canada M	Petro-Canada O	Petro-Canada N	Petro-Canada S	Husky M	Husky O	Husky N
Oil and Grease	0	0	0	8	0	0	0	0	0	0	0
Total Suspended Solids	0	0	0	9	0	0	0	0	0	0	0
Phenols	0	0	0	0	0	0	0	0	0	0	0
Sulphide	0	0	0		0	0	0		0	0	0
Ammonia Nitrogen	0	0	0		0	0	0		0	0	0
pH			14				0				4
Toxicity			0				0				0
Total	0	0	14	17	0	0	0	0	0	0	4
Percentage of Region	0	0	47	81	0	0	0	0	0	0	13
Percentage of Time in Compliance	0	0	5.7	47.2	0	0	0	0	0	0	1.5

b) Number of Monthly Amounts Exceeding the Limits by:	Esso	Petro-Canada	Husky
0 to 24%	9	0	0
25 to 49%	1	0	0
50 to 99%	6	0	0
100 to 199%	1	0	0
200	0	0	0

a) Combined refinery and gas plant effluent.
b) Effluent receives additional treatment off-site.
* M: Monthly amount; O: One-day amount; N: Maximum daily amount; S: Stormwater monthly amount.
** Actual deposits in bracket are for stormwater (annual average).
*** Standard deviation expressed in percent.

	Refinery		
	Esso Ioco	Petro-Canada Port Moody	Husky Prince George
Reference Crude Rate ($10^3\ m^3/d$)	6.68	5.41	1.38
Status	Existing	Existing	Existing
Number of Months in Operation	12	12	12
Number of Tests Reported	245	314	262

Shell[b] Burnaby	Petro-Canada[a] Taylor	Chevron[b] North Burnaby		Region	
Actual Deposits	Actual Deposits	Guideline Deposits	Actual Deposits	Authorized Deposits	Actual Deposits
11.7 ± 53% (1.55 ± 110%)	1 ± 39% (.44 ± 177%)	14.1 (3.9)	6.82 ± 49% (1.48 ± 67%)	16.5 (4.56)	4.4 (2.31)
24.9 ± 52% (4.81 ± 95%)	2.21 ± 67% (30 ± 196%)	33.9 (11.8)	28.5 ± 47% (2.4 ± 70%)	39.3 (13.2)	15.6 (9.9)
0.21 ± 89% (0.006 ± 83%)	0.01 ± 67% (.13 ± 115%)	1.42 (0.38)	0.48 ± 118% (0.08 ± 40%)	1.6 (0.46)	0.33 (0.10)
0.12 ± 24%	.4 ± 12%	0.5	0.10 ± 177%	0.57	0.11
6.06 ± 86%	.74 ± 48%	12.9	1 ± 73%	14.0	2.4

M	O	N	S	M	O	N	S	M	O	N	S	M	O	N	S
3	0	0	1	0	0	0	0	0	0	2	1	3	0	2	10
1	0	0	1	0	0	0	1	4	1	1	0	5	1	1	11
0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0
0	0	0		0	0	0		0	0	0		0	0	0	
2	0	1		0	0	0		0	0	0		2	0	1	
		0				1				5				24	
		0				0				1				1	
6	0	1	2	0	0	1	1	5	1	10	1	11	1	30	21
55	0	3	9	0	0	3	5	45	100	34	5				
10	0	0.3	7.1	0	0	0.3	6.7	9.1	0.5	4.1	2.8	3.2	0.1	1.8	13.9
	5				0				2				16		
	3				0				4				8		
	0				0				0				6		
	0				0				0				1		
	0				1				0				1		

Shell Burnaby	Petro-Canada Taylor	Chevron North Burnaby	Region
2.245	2.03	5.88	23.625
Existing	Existing	Existing 3.82 + Expanded 2.06	Existing 21.565 + Expanded 2.06
12	12	12	
294	314	254	1683