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TOWARDS CLEANER PRODUCTION IN THE OIL AND GAS INDUSTRY IN THE ESCWA COUNTRIES

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This study has been prepared by Dr. Essam El-Hinnawi, Research Professor, National Research Centre, Dokki, Cairo. The views expressed in this study are those of the author and do not necessarily reflect those of the United Nations Economic and Social Commission for Western Asia.

CONTENTS

PREFACE

There is now a growing realization in industry, in developed as well as in developing countries, that " Prevention is Better than Cure "; and this has created increasing interest in developing and introducing cleaner production technologies. The importance of such technologies has been emphasized by the Conference on Ecologically Sustainable Industrial Development, organized by UNIDO in Copenhagen in 1991. This was also stressed in the Arab Programmes for Sustainable Development, adopted by the Council of Arab Ministers Responsible for Environment (CAMRE) in 1992. The CAMRE's programme on industry emphasizes the identification of the different environmental problems of industry to determine the best applicable means to reduce or eliminate the undesirable impacts. AGENDA-21, adopted by the United Nations Conference on Environment and Development in Rio de Janeiro in 1992, emphasized the importance of reducing emissions and waste from industries in Chapters 18,19,20,21 and 30. The latter outlined the objectives of promoting cleaner production. It pointed out that " *Governments, business and industry, including transnational corporations, should aim to increase the efficiency of resource utilization, including increasing the reuse and recycling of residues, and to reduce the quantity of waste discharge per unit of economic output*". Chapter 30 outlined a number of activities to be undertaken to achieve these objectives. It called on international and regional organizations and on NGOs including trade and scientific associations, to strengthen cleaner production information dissemination, and to increase education, training and awareness activities relating to cleaner production.

ESCWA's Programme for 1992-1997 seeks to enhance sustainable development through the promotion of regional and subregional cooperation and to provide opportunities for the acceleration of the process of sustainable development in each of the ESCWA member countries. Among the overall strategy of the programme, ESCWA should :(1) carry out research and surveys to monitor developments, including emerging issues, and propose action for the sustainable development of the region; (2) provide advisory services to States members of the Commission, to enhance their policy-making and institutional capacity to achieve sustainable development; and (3) develop close cooperation and coordination with bodies of the United Nations to avoid duplication and ensure complementarity and exchange of information.

In the ESCWA region, the notion that " environmental protection makes the production of goods and services more costly and therefore is a luxury developing countries cannot afford" is now being gradually eroded by the recognition that environmental protection is indeed an investment into the future, and is a prerequisite to achieve sustainable development. An increasing number of public and private industries in the ESCWA region is becoming interested in environmental management and in introducing cleaner production techniques. The enactment of national environmental protection regulations has partly prompted this interest. Another factor has been the growing shift of international industries towards " greener" production.

The present report deals with the opportunities of increasing the use of cleaner production techniques in the oil and gas industry in the ESCWA region, which is the major extractive industry in the region. The report consists of six chapters. The first chapter gives an introduction to the subject of cleaner production and its benefits. The second, gives a summary of the status of the oil and gas industry in the ESCWA region. Chapters 3, 4, 5, and 6 outline the technologies and environmental aspects of the oil and natural gas fuel cycles (the fuel cycle is defined as the entire programme from the extraction of raw material, through transportation, processing, storage, use of the fuel, to the management of wastes produced in all steps of the cycle). In each of these chapters examples of the options for pollution reduction (cleaner production) are given.

CHAPTER 1

INTRODUCTION

Industry is central to the economies of modern societies and an indispensable motor of growth. It is essential to developing countries, to widen their development base and meet growing needs. And though industrialized countries are said to be moving into a post-industrial, information-based era, this shift must be powered by a continuing flow of wealth from industry (WCED, 1987).

The industrial sector is an important user of natural resources and is the major contributor to the World's pollution loads. The traditional model of industrial activity is one which takes in raw materials and generates products to be sold plus waste to be disposed of. The negative environmental impacts of industrial activity were initially perceived as localized problems of air, water, and land pollution. It is becoming increasingly clear, however, that the sources and causes of pollution are far more diffuse, complex, and interrelated - and the effects of pollution more widespread, cumulative, and chronic - than hitherto believed. Pollution problems that were once local are now regional or even global in scale (El-Hinnawi, 1995).

Growing awareness and public concern over environmental pollution led to action by governments and industry in both industrial and some developing countries (UNEP, 1992). Environmental protection and resource conservation policies and programmes were established, along with agencies to administer them. Initially policies focussed on regulatory measures aimed at reducing emissions. Later, a range of economic instruments were considered- taxation, pollution charges, and subsidies for pollution control equipment.

Until recently, industry has responded to environmental pollution problems by instituting regulations and technologies to manage the different emissions and wastes generated (the so-called " end-of-pipe" treatment). This has proved to be both difficult and costly, and achievements have been limited to some industrial countries.

The commonsense, precautionary response to burgeoning pollution problems is to seek to prevent pollution before it happens. Where it is already occurring, the aim should be to eliminate the source of the problem rather than attack symptoms through often expensive "end-of-pipe" methods such as filters, scrubbers, treatment plants, and incineration. More and more companies are realizing that the pollution they produce is a sign of inefficiency. A combination of increasing regulatory pressures, mounting public expectations, and tightening competitive conditions is now driving companies everywhere to adopt the logic of pollution prevention.

Hence, the concept of waste reduction or prevention has been gradually introduced. The idea of introducing "low-waste technologies " emerged particularly in the mid-1970s; and it became apparent since then that the principle of " Pollution Prevention Pays" should be widely promoted. Its benefits are enormous. Occupational and public exposure to hazardous chemicals is reduced; industrial efficiency and competitiveness are enhanced as waste prevention simultaneously cuts raw material input, saves energy, and reduces the volume of waste to be stored, treated, or disposed of. Less waste means less expenditure on buying and operating pollution control equipment; accidents during transportation of waste are reduced; the need for offsite waste facilities are reduced, which also reduces associated health, environmental and political problems.

By the mid-1980s, there was an increasing recognition that the industrial system should be looked at as an "industrial ecosystem". In such a system the consumption of energy and materials is optimized, waste generation is minimized and the effluent of one process serve as the raw material for another. This "greening" of industry has been demonstrated in several countries, especially in developed countries, by increasing the efficiency of energy and water use, increasing recycling of waste, and the development of cleaner technologies (Frosch and Gallopoulos, 1989; UNEP, 1992).

1. Cleaner Production

In a broad sense, cleaner production means the continuous application of an integrated preventive environmental strategy to processes and products to reduce risks to humans and the environment. The goal of cleaner production is not to generate waste in the first place. Cleaner production is achieved by applying know-how, improving technology, and/or changing attitudes.

In the last few years, the economic feasibility and environmental benefits of introducing cleaner production techniques in several industries have been demonstrated. The 3M Company (Minnesota Mining and Manufacturing, USA) executed a programme covering several projects. The programme saved the company $ 420 million over 10 years and prevented the annual discharge of 12,000 tonnes of air pollutants, 14,000 tonnes of water pollutants, and 313,000 tonnes of sludge and solid waste. Exxon Chemical Co.,USA, installed 16 floating roofs on open tanks of volatile chemicals at its Bayway Plant. This resulted in annual savings of 340 tonnes of organic chemicals, worth about $ 200,000 in addition to a marked reduction of releases into the environment. A third example, is that of the waste reduction programme initiated by DOW Chemical Company in 1984. The implementation of that programme in the company's California plant resulted in about 93% reduction of waste generated between 1984 and 1988 (Schmidheiny, 1992; UNEP, 1992).

In Europe, the PRISMA project (Project on Industrial Successes with Waste Prevention) was initiated in 1985 by the Netherlands Organization of Technology Assessment. Some 165 pollution prevention options were identified. In 30% of the cases these changes were in the category of good house-keeping; another 30% in raw materials; 30% in changes in equipment; and the rest in process modifications. Some good house-keeping resulted in 25 to 30% reductions in chemicals used in some companies. In a number of other companies, technological changes resulted in reductions in waste and emissions of 30 to 80%. By the early 1990s, the PRISMA project has spread to other European countries; and in 1990 the EUROENVIRON Programme (a part of EUREKA, the co-operative research programme in Europe) began promoting PREPARE (Preventive Environmental Protection Approaches in Europe). PREPARE seeks to catalyze industry/government co-operation and the transfer of information on pollution prevention and cleaner production.

2. Ways and Means of Cleaner Production

The myriad of pollution prevention possibilities can be divided into four main categories: good housekeeping, materials substitution, manufacturing modifications, and resource recovery. Often companies employ a number of these approaches simultaneously to resolve a particular problem.

The aim of good housekeeping is to operate machinery and production systems in the most efficient manner. As such, it is a basic task of management. For example, the proper operation and regular maintenance of equipment can often substantially reduce leakage and overuse of materials. Improvements in housekeeping practices, which can often reduce pollution by between a quarter and a third, usually do not require large capital expenditures. Good housekeeping requires attention to detail and constant monitoring of raw material flows and impacts. Many companies still have no idea how much or what types of wastes and pollution they produce. Waste minimization and pollution prevention start from the basis of accurate measurement, identifying and then separating wastes. Improvements in information technology have also made environmental monitoring more affordable. Some companies have introduced sophisticated waste measuring and tracking systems.

Identifying and eliminating sources of pollution often implies restructuring for both producers and consumers. Full or partial phaseouts of lead, mercury, DDT, and chlorofluorocarbons (CFCs) have been implemented in various parts of the world as the only effective ways of solving the problems they cause. There are many examples of materials substitution in car manufacturing, iron and steel industries, and the chemical industry (UNEP, 1992).

Often companies can considerably reduce emissions by simplifying production technology through lowering the number of process stages. Switching to closed-loop processing can also conserve resources and cut noxious emissions. Water consumption and pollution can also be reduced through recycling programmes. Sometimes, more fundamental changes, such as moving from a chemical to a mechanical process, can help prevent pollution.

Pollution emissions can also be reduced by keeping the polluting agents within the production system, and reusing them in the same or other processes. Some industries have already established complex "industrial ecosystems" whereby the waste from one process becomes the feedstock for another. Many large-scale petrochemical operations have extensive recycling circuits, which are used to return materials such as solvents or catalysts to the beginning of the process. Materials that are waste for one industry can be useful inputs in another. Waste exchange systems have been established in a number of countries to facilitate the exchange of wastes between producers and potential customers.

3. Obstacles to Cleaner Production

Three broad types of obstacles to the spread of pollution prevention within industry can be identified : economic, information, and management attitudes.

First, companies must be convinced that the introduction of a new, cleaner technology, will really cut production costs. Going to the source of a pollution or resource use problem challenges existing ways of doing business, and can thus be seen by industry as more risky. Although substantial gains can be achieved through improved efficiency and better housekeeping, there comes a point where significant technological change and investment are required. Smaller companies and those in developing countries are often not in a position to make such investments.

The second obstacle is a lack of information. Practical data about pollution prevention options may be unavailable, while much information that is available (and promoted by environmental technology companies) stresses end-of-pipe solutions. Companies often need local examples from their own industrial sector that demonstrate both the benefits and the feasibility of pollution prevention. Within companies, information on environmental impacts is often poor, making it difficult to assess prevention projects.

The third and most important obstacle is management attitude. Many managers believe that environmental protection inevitably costs money, that it is a peripheral issue and a diversion from basic corporate goals. This attitude has been supported by the use of end-of-pipe controls that are unproductive and simply add costs to the business.

Developing-country industries may be less able to afford investments in pollution prevention, but they are also least able to afford the loss of resources and efficiency represented by traditional patterns of industrial development. Developing countries also cannot afford the costs of waste management, which within industrial nations are now regarded as a heavy financial burden on the economy. For example, traditional industrial patterns in the developed countries have created the major problem of hazardous wastes that have accumulated without proper management over decades. The cleaning of priority hazardous waste sites in the United States alone is expected to cost hundreds of billions of dollars (UNEP, 1989, 1992).

By avoiding such burdens through pollution prevention, developing countries could increase their international competitiveness while improving environmental quality. Whether they can " leapfrog" the industrial world in this way depends greatly on the quality and effectiveness of the technology that is transferred from North to South.

The conceptual and technological foundations for achieving cleaner processes and products have already been laid. There is considerable and growing experience of pollution prevention. But sustainable development means more than this, and in the years ahead business will be challenged to achieve near-zero pollution emissions from production plants and to redirect product development to meet basic needs. Therefore, resource and environmental considerations must be integrated into the industrial planning and decision-making processes of government and industry. This will allow a steady reduction in the energy and resource content of future growth by increasing the efficiency of resource use, reducing wastes, and encouraging resource recovery and recycling.

CHAPTER 2

THE OIL AND GAS INDUSTRY IN THE ESCWA REGION

The ESCWA region is the richest region in the world in oil and natural gas resources. The total proved recoverable oil reserves amount to 56 % of the world reserves (Table 1), whereas the natural gas reserves constitute about 17 % of the world total (Table 2). In 1992, the ESCWA region produced 26 % of world oil, and 6.5% of world natural gas (Tables 3 and 4). Oil exports from the ESCWA region constituted about 39 % of total oil export market in the world in 1992.[1]

Table 1 Estimated Proved Recoverable
Oil Reserves in the ESCWA Region (1992)

Country	**Oil Reserves (Billion barrels)**
Bahrain	0.1
Egypt	3.4
Iraq	100.0
Jordan	0
Kuwait	96.5
Oman	4.5
Qatar	4.5
Saudi Arabia	261.2
Syria	1.7
UAE	98.1
Yemen	4.0
Total ESCWA	574.0
Total Arab Countries	611.6
Total World	1033.0

Source : OAPEC (1994)

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[1]. For more details on the oil and natural gas production in the ESCWA region, the reader is referred to the many papers presented at the Fifth Arab Energy Conference convened in Cairo in 1994.

Table 2 Estimated Proved Recoverable Natural Gas Reserves in the ESCWA Region (1992)

Country	**Natural Gas Reserves (Billion cubic m)**
Bahrain	160
Egypt	362
Iraq	3100
Jordan	6
Kuwait	1845
Oman	453
Qatar	7079
Saudi Arabia	5249
Syria	250
UAE	5795
Yemen	394
Total ESCWA	24333
Total Arab Countries	29395
Total World	145986

Source : OAPEC (1994)

Table 3 Oil Production in the ESCWA Region (1992)

Country	**Oil Production (1000 barrels/day)**
Bahrain	30
Egypt	836
Iraq	526
Jordan	0
Kuwait	1058
Oman	731
Qatar	423
Saudi Arabia	8332
Syria	513
UAE	2266
Yemen	168
Total ESCWA	14883
Total Arab Countries	17197
Total World	58451

Source : OAPEC (1994)

Table 4 Natural Gas Production in the ESCWA Region (1992)

Country	**Natural Gas Production (Billion Cubic m)**
Bahrain	6.5
Egypt	9.9
Iraq	3.1
Jordan	0.2
Kuwait	5.3
Oman	3.8
Qatar	13.0
Saudi Arabia	61.1
Syria	1.1
UAE	33.1
Yemen	0
Total ESCWA	137.1
Total Arab Countries	213.1
Total World	2100.0

Source : OAPEC (1994)

The oil industry is the major industry in the ESCWA region, accounting, on average, for about 22 % of total gross domestic product (GDP) in 1992 (LAS, 1994). For the Gulf countries, the contribution of the oil industry to national GDP varied from 18 % in Bahrain to as much as 43 % in Kuwait and Oman, in the same year.

Not all the crude oil produced in the ESCWA region is exported; part of it is refined to various products. Oil refining has in fact been expanding considerably in the region. In 1980, there were 30 oil refineries in the ESCWA region that produced about 1.9 million barrels of refined products every day. In 1991, the number of refineries reached 39 and produced about 3 million barrels of refined products every day (ESCWA, 1992). Table 5 gives the distribution of oil refineries in the region and their installed capacity. These refineries vary from the simple topping refineries to the more sophisticated and complex petrochemical and integrated ones. In fact there is now a wide array of petrochemicals produced in the ESCWA region, for example, ethylene, polyethylene, ethylene dichloride, vinyl chloride, ethylene glycol, methanol. acetic acid, butadiene, formaldehyde, and others. Several projects are being planned to expand petrochemicals production, especially in Egypt, Qatar and Saudi Arabia.

In contrast to the oil industry, the natural gas industry is still at its early stages in spite of the fact that natural gas has been used as feedstock in several industries in the Gulf countries and elsewhere in the ESCWA region (for example, for manufacturing fertilizers, as fuel in the iron and steel industry, and for electricity generation). The only plant for natural gas liquefaction is in the UAE, producing 2.3 million tonnes per year. Five natural gas liquefaction projects (4 in Qatar and one in Oman) are under study, with a total output of 32 million tonnes per year.

Table 5 Oil refineries in the ESCWA Region (1992)

Country	**No.of Refineries**	**Installed capacity (million tonnes)**
Bahrain	1	12.60
Egypt	7	28.00
Iraq	10	27.51
Jordan	1	4.62
Kuwait	3	37.93
Oman	1	3.60
Qatar	1	2.75
Saudi Arabia	9	87.41
Syria	2	11.12
UAE	2	8.46
Yemen	2	9.10
Total	39	233.10

Source : OAPEC (1994)

CHAPTER 3

OIL AND NATURAL GAS PRODUCTION

I. OIL PRODUCTION

Crude oil exists in and is extracted from underground rock formations, known as reservoirs. Within an oil reservoir, there may be varying amounts and kinds of a mixture of naturally-occurring materials: dissolved gases within the crude oil, dissolved gases in the brines associated with the oil, free gases that occur with the crude oil, and brines.

1. Onshore Production

1.1 Primary Production :

The technology surrounding the drilling of oil wells is undergoing constant development. Drilling forms the final test of the exploratory stage and the first step of the production stage. A number of appraisal wells have to be drilled into potential reservoir structures once oil has been found, to determine exactly how much oil is present and its quality, before a realistic decision can be made on whether to exploit the reservoir. Development wells are then drilled to extract the oil and to preserve the reservoir's pressure for as long as possible.

In the drilling process considerable amounts of drilling mud (a well about 3500 m deep would require about 1200 to 2500 barrels of drilling mud) are used to lubricate the drill string, cool the rotary drill bit, carry the rock cuttings/fines from the well bore to the surface, inhibit the entrance of undesirable formation fluids into the well bore, and control excessive pressure in the well bore to prevent blowouts (Wilkins, 1977). The drilling mud is composed of mixtures of clay, water, and various chemical compounds. Some of the more commonly used compounds are: lignosulphonates, acrylonitrile, caustic lignin and tanin, emulsified asphalt and formaldehyde. Several of these compounds have been shown to be carcinogenic in animals. In addition, the drilling muds often contain formation cuttings that must be separated when they reach the surface (to reuse the drilling mud). Often the mixture of cuttings and drilling mud is contaminated with associated crude oil. Due to their varied compositions, the mud formulations and mud/cuttings mixtures may introduce large amounts of potentially hazardous compounds into the work site.

In conjunction with drilling, a direct threat to the health and safety of workers may arise as a result of well blowouts, especially in the drilling of deep wells. In addition to causing direct injury, blowouts also cause the release of aerosols and poisonous gases such as hydrogen sulphide. If fire is associated with such an event, carbon monoxide, oxides of sulphur and nitrogen, and particulate matter also would be emitted.

Once drilling has reached an economic reservoir, the oil well is completed, and prepared for handling oil production. In most cases the reservoir's own internal pressure provides a natural drive to lift the oil to the surface - in effect forcing the oil through the rock pores to the well and then up to the surface, usually through a process of displacement, with water pushing from below or from gas pushing down on the oil from the top of the reservoir. Frequently, a combination of these two natural drives exists. However, the level of reservoir permeability can prove a major problem when it prevents sufficient oil flow. The permeability of the reservoir rock is, therefore, important in setting the rate of oil flow from a well. Two main methods to improve permeability exist- hydrofracturing and acidizing. In the case of hydrofracturing, water under pressure is forced into the reservoir, causing fractures to open in the rock. Acidization is usually used in limestone reservoirs. An acid solution is pumped into the reservoir structure to etch out, or create paths through the rocks and enlarge the pore space, so improving the oil flow.

1.2 Enhanced Oil Recovery :

Enhanced oil recovery is the use of any technique to extract more oil than that which is obtained through primary production. The various techniques are divided into two categories : secondary and tertiary methods.

1.2.1 Secondary recovery :

Secondary recovery techniques include the injection under pressure of either treated water or immiscible natural gas into an oil formation to increase the oil flow. The injection of water, termed water-flooding, is the most important of these two techniques. Waterflood operations utilize two types of wells: production and injection wells. Treated water is pumped into the injection well and down to the oil containing formation. The injected water forces trapped oil held within the formation into the production wells where water pressure forces the oil to the surface of the reservoir. The production fluid reaching the surface is a mixture of oil and injected water.

The injected water usually requires treatment with various chemicals to prevent scale formation, inhibit corrosion, and prevent the growth of microorganisms. The nature and extent of the chemicals added to the injection water are of environmental importance, since surface and sub-surface contamination can result from spillage or seepage of these fluids.

1.2.2 Tertiary recovery :

There are four major tertiary recovery techniques: hydrocarbon-miscible flooding; carbon dioxide miscible flooding; surfactant and polymer flooding; and steam and in situ combustion techniques. The first three methods reduce surface tension between oil and the driving fluid, while the last one employs heat to reduce the viscosity of the oil.

Enhanced recovery methods involve worker exposure to many kinds of potentially toxic substances, including sequestering agents, anticorrosives, phenols, co-surfactants, bactericides, and various polycyclic hydrocarbons associated with crude oil. The potential risks to public health depend on the location of population with respect to production areas. With the increasing use of advanced recovery techniques, many new kinds and combinations of gases and aerosols may be released to the atmosphere. The effects of these on adjacent communities and their interactions with other airborne pollutants remain to be evaluated.

2. Offshore Production

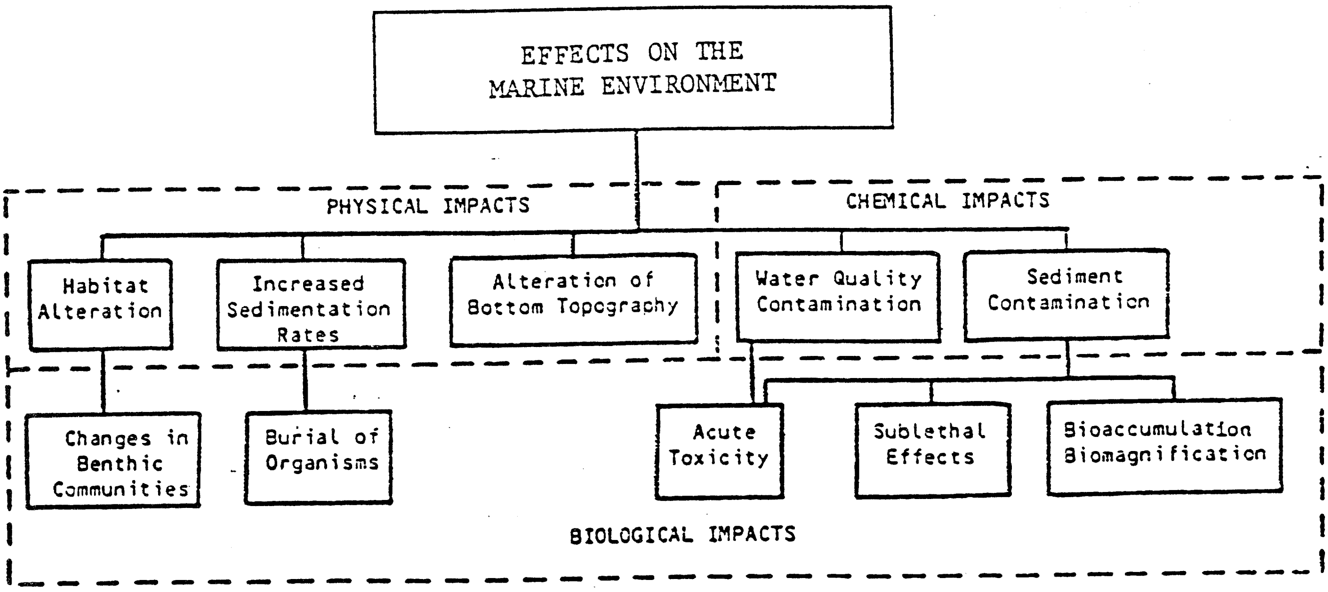
Over the years a wide range of tools and technologies for offshore oil production have been developed. Today some of the offshore drilling rigs are the largest moveable structures in the world. As drilling has moved further offshore and into some extremely inhospitable conditions, these rigs have become self-supporting and self-contained, maintaining everything from accommodation for the crew to basic treatment facilities for crude and crude storage tanks. The drilling and production technologies are essentially the same as those described under onshore production outlined above.

Offshore oil production would have its greatest potential impact on human health within the workplace, although the general public could be affected if the industry causes contamination of the marine food chain leading to man, and the emission of airborne pollutants from offshore production or port complexes.

The discharge of drilling muds into the sea from offshore operations can result in a range of physical, chemical and biological effects in the marine environment (Fig.1). The areas of greatest concern are that the muds may be acutely toxic or may produce deleterious sublethal responses in sensitive marine species; and metals and organic compounds present in some drilling fluids may accumulate in marine organisms to concentrations that would harm marine life or human consumers of fishery products (Neff, 1980; Trocine and Trefry, 1983).

Fig.1

The Environmental Impacts of Drilling Muds



3. Treatment of Extracted Crude Oil

Raw crude oil, as it comes out of a well often contains quantities of gas or salt water (brine). Frequently both are present along with other impurities such as sand. These have to be separated out of the raw crude before it is transported in pipelines and tankers to refining centres. Usually, such separation takes place near the production wells in a simple flow tank when the gas content in the crude oil is low. If a considerable amount of gas is present, and particularly if the crude oil is produced under considerable pressure, a series of flow tanks are used (multi-stage separation). When the amount of gas is too small or where economic incentives do not justify further gas processing steps, the gas is either vented to the atmosphere or burned (flaring). This results in various airborne emissions (hydrocarbons, sulphur oxides, particulate matter).

The salt water associated with the produced crude oil may exist as free water and as oil-water emulsion. In the first case, the water is gravimetrically separated from the oil. Water-oil emulsions require more elaborate treatment techniques to achieve separation of the two components. Heaters and electric dehydrators are used to physically separate the oil from the brine. Chemicals may also be added to destabilize emulsions. Once the mixture is broken into two separate phases, gravitational settling can occur and the brine can be drawn off and disposed of. A considerable amount of brine may remain after crude oil separation. It is estimated that 2-3 cubic metres of brine are produced for every cubic metre of oil (Wilkins, 1977). The majority of this brine (72%) is disposed of in underground formations or used for injection purposes during secondary recovery. The remainder may be disposed of in the sea or non-potable water bodies.

4. Oil Spills

The entire sequence in the development of offshore oil reserves carries with it the potential for oil leaks and oil spills. The release of oil to the environment may result from blowouts or natural seeps during the drilling, well completion, or production processes; from the transfer of oil from platforms to tankers or tankers to storage facilities; from oil pipeline leaks; or during tanker washing or ballasting operations.

The extent of the damage caused by oil spills depends on several factors including the location of the spill (near shore or in the open ocean), the weather and the composition of the oil. Although there is no evidence that oil spills from tanker accidents have caused damage to the open ocean and its living resources, spilled oil can affect coastal zones, where oil may persist for several decades (NRC, 1985; GESAMP, 1990).

An oil spill can harm wildlife that ingests petroleum or loses the insulating capacity of its feathers. Oil spills have drastic implications for oceanic and diving birds. In addition to direct kills of organisms, the major adverse environmental effects of direct oil pollution or coastal waters are: disruption of feeding and reproductive activities of aquatic species; changes in physical and chemical habitat, causing exclusion of species and reduction of populations; and stresses on the ecosystem from decomposition of effluents, resulting in altered productivity, metabolism, system structure, and species diversity (GESAMP, 1990). Some of the major components of fish and wildlife species and habitats that are affected include: endangered birds; migratory waterbirds; shellfisheries; coastal finfish; estuarine finfish; wetlands; wildlife refuges and management areas and national recreation areas. Although studies of oil spills have shown that affected environments do recover with time, there is growing concern about the long-term effects of exposure of marine biota to low levels of hydrocarbons.

5. Environmental Impacts of Oil Production in The ESCWA Region

The above-mentioned environmental impacts are encountered in the ESCWA region to varying degrees. They are on the rise given the rapid increase in oil producing wells (in 1980 there were 3804 oil wells in the ESCWA region; in 1991 the number rose to 6694 wells (ESCWA, 1992)). The environmental impacts of oil production are particularly encountered in the Gulf, which is an almost closed sea and the site of many offshore oil operations, loading terminals and oil shipping. The Persian Gulf has an average depth of only 35 m. It is highly saline, with salinities varying generally from about 38 to 70 per thousand. The annual range in seawater temperatures is high both near the coast (10-39 degrees C) and offshore (18-33 degrees C). Because of these conditions, the turnover and flushing time of the Gulf have been estimated to be in the range of 3-5 years (Price and Sheppard, 1991). Consequently, pollutants entering the Gulf are likely to reside there for a considerable time.

Several studies (for example, UNEP, 1981, 1984; El-Samra et al.,1986; Coles and Gunay, 1989; Price and Sheppard, 1991) have documented the pollution of the Gulf as a result of oil production. It has been estimated that about 159,000 tonnes of oil find their way into the waters of the Gulf each year. Of these, about 127,000 tonnes are from offshore oil production, loading terminals and tanker operations. This oil pollution is not confined to a particular country in the region, but constitutes a transboundary pollution problem. Hot spots, with marked concentration of hydrocarbons are present near oil production installation and terminals (El-Samra et al.,1986). Oiling of beaches is common in most countries of the Gulf region, and Coles and Gunay (1989) pointed out that beach tar levels in the Gulf are by far the highest recorded anywhere in the world.

Table 6 gives estimates of the pollution loads encountered in the Gulf as a result of oil production operations.

Table 6 Estimates of pollution loads due to oil production in the Gulf.

Ship ballast discharges : -Waste volume : 397 million cubic m /year -oil in the waste : 597,000 tonne/year			
Oil sludge : Oil sludge from tank farms where crude oil is stocked for shipment. Oily sludge : 970,000 t/year (This sludge is disposed of on land and most of it burned periodically causing air pollution).			
Air emissions :			
	Gas flaring	Oil terminal	Sludge burning
Sulphur oxides t/y	2,200,000		10,700
NOx t/y	240,000		370
Hydrocarbons t/y	15,500	116,800	18,000
Carbon oxide t/y	25,000		13,000

Source : Calculated from UNEP (1981)

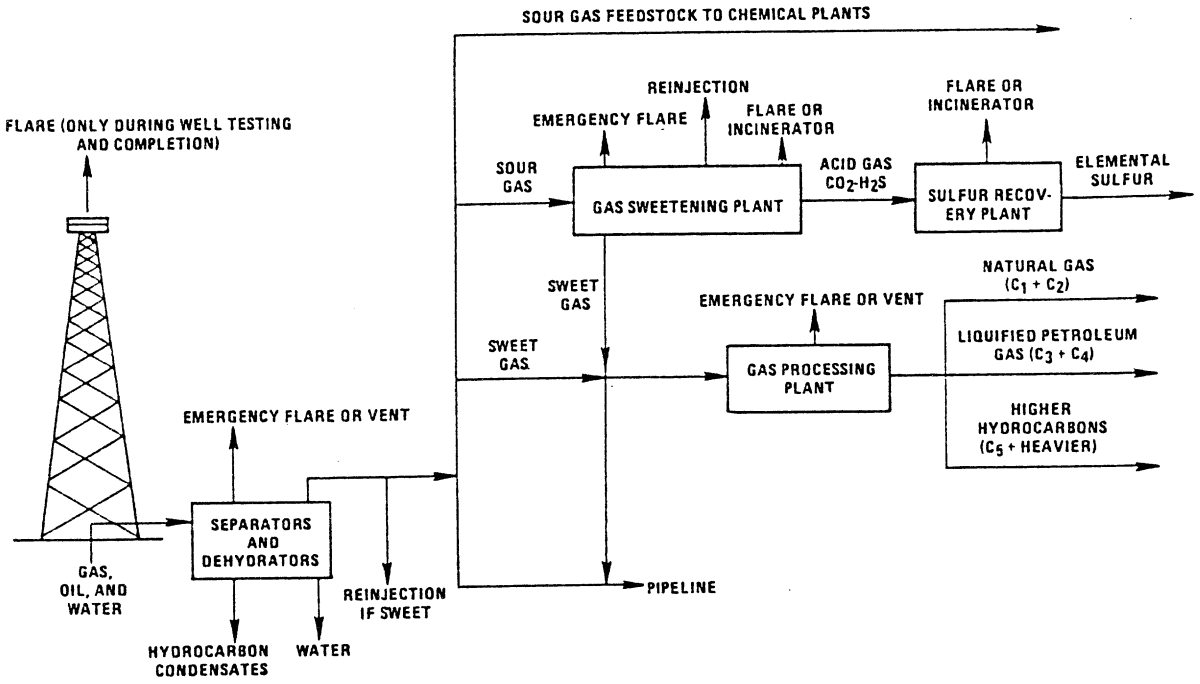
II. NATURAL GAS PRODUCTION

Natural gas occurs in four types of reservoir situations : dissolved gas within crude oil deposits; associated (free) gas occurring with crude oil (e.g. in gas caps); non-associated gas; and gas dissolved within brines. The basic drilling procedures and associated environmental impacts are similar to those outlined above under oil production.

Natural gas associated with crude oil must be separated from the oil at the production site, using separators, before being sent for further processing (see under treatment of extracted crude oil above). Whether associated with oil or found by itself, natural gas may contain hydrogen sulphide which must be removed before further processing. Natural gas is considered "sour" if hydrogen sulphide is present in amounts greater than 6 mg/cubic metre. The removal of hydrogen sulphide is carried out by passing the sour natural gas in an amine solution (known as "sweetening" of the gas). Mono, di, or triethanolamine solutions are used. Subsequently, the amine solution is stripped of the hydrogen sulphide and recycled (Fig.2).

Fig.2

Natural Gas Production



The recovered hydrogen sulphide gas stream may be vented, flared in waste gas flares, incinerated, or utilized for the production of elemental sulphur or other commercial products. If the recovered hydrogen sulphide gas stream is not to be utilized as a feedstock for commercial applications, the gas is usually passed to a tail gas incinerator in which the hydrogen sulphide is oxidized to sulphur dioxide and then passed to the atmosphere via a stack. In a gas sweetening plant the emission of sulphur oxides has been estimated at about 27 kg/1000 of cubic metres of natural gas processed (EPA,1985).

Enhanced natural gas production methods include hydraulic fracturing techniques, chemical explosive fracturing, and directionally-controlled drilling (see also under enhanced oil recovery above). Whatever type of enhanced recovery technique is used, when the gas reaches the surface it will be separated from impurities as described above.

III. POLLUTION REDUCTION

Oil production and transportation has rapidly developed over the years. Many technologies and safety measures have been introduced to prevent and/or contain accidents if they occur, thereby protecting workers, the near-by population and the environment. Yet, there are many options for improvements to reduce different emissions and wastes discharged from oil production operations.

For example, in the 1970s, drilling fluids were mostly oil-based. Because effluent limitations prohibit the discharge of free oil in the marine environment, the spent oil-based muds cannot be discharged into the sea. Compliance with these limitations can be achieved either by product substitution (substitute a water-based mud for an oil-based mud; substitute mineral oil for diesel oil to comply with no free oil limitations for water-based muds); recycle and/or reuse of the drilling fluid; or by onshore disposal at an approved facility (EPA, 1993). At present, most drilling fluid systems are water-based, although oil-based systems are still used for specialized drilling projects. The best practicable control technology (BPT) currently available restrict the oil and grease concentrations of produced water to a maximum of 72 mg/l for any one day, and to a thirty day average of 48 mg/l (EPA, 1993).

Hydrocarbon emissions from storage tanks may be reduced by the use of segregated ballasting, tank cleaning, slow loading, short loading, and the routing of vapours into tanks that are being emptied.

The largest source of contaminated wastewater at a crude terminal is the ballast water from tankers. The quantity of ballast water requiring treatment depends upon the ship design, operation, and regulations governing the discharge of ballast waters. The ship design parameters include the amount of segregated ballast, the tank geometry, and the use of on board oil/water separators. The operating parameters include the type of previous cargo, weather conditions, and tank-cleaning procedures. Optimizing the design and operation of a tanker can reduce the amount of wastewater requiring treatment.

Solid and semi-solid wastes, such as tank bottoms and separator box solids, usually are not generated at a terminal if the crude storage tanks are kept well mixed and all of the contents are sent to the refinery for processing. Crude shipping facilities, however, may generate solid wastes from the treatment of ballast water. Management of these wastes can be handled as for refinery wastes (see later).

CHAPTER 4

OIL REFINING

1. TYPES OF REFINERIES

Oil refineries are usually classified into the following five types :

(1.1) Topping refinery (subcategory A) :

The topping refinery (Fig. 3) is the simplest of the basic refinery types. Topping refers to the use of simple fractionation (distillation) processes to obtain straight run fractions such as naphtha, middle distillate, and fuel oils from crude oil. Catalytic reforming, hydrotreating, and sweetening may be used (for definition of these processes, see later). The topping refinery's basic processes are essentially duplicated in the other categories of refineries.

(1.2) Cracking refinery (subcategory B) :

A cracking refinery (Fig.4) performs catalytic or thermal cracking, besides the basic topping refinery operations. Cracking significantly increases the proportion of lighter aromatics fractions. Heavy and middle distillates are cracked to produce lighter hydrocarbons with a higher octane rating for blending into gasoline, kerosene, jet fuel, and fuel oils.

(1.3) Petrochemical refinery (subcategory C) :

The petrochemical refinery (Fig. 5) adds petrochemical operations to those of the topping and cracking categories. Petrochemical feedstocks, such as olefins and BTX (benzene, toluene, and xylene) fractions, are included among major products for subsequent petrochemical manufacture.

(1.4) Lube refinery (subcategory D) :

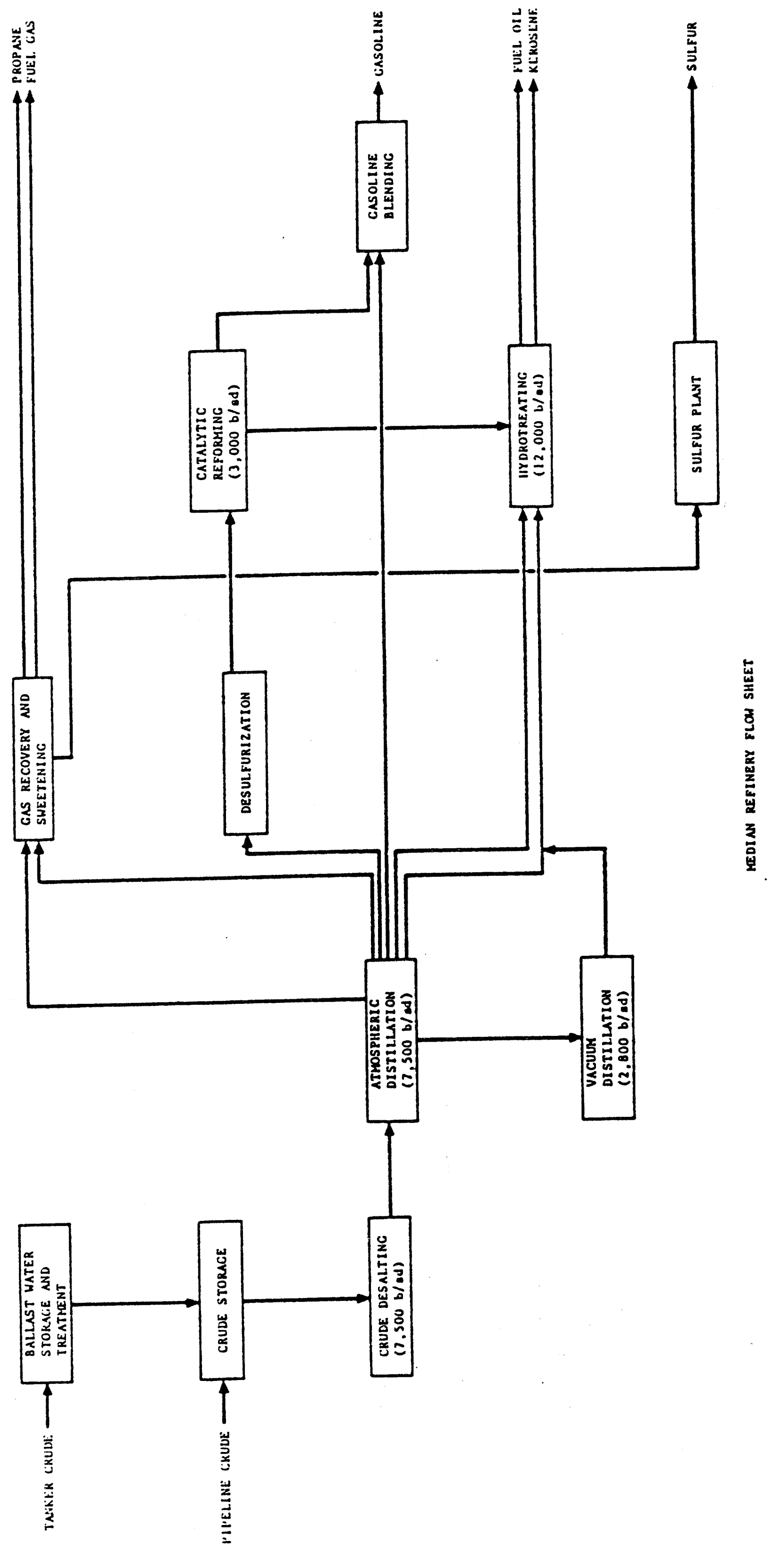
The lube refinery (Fig. 6) adds lubricating oil manufacturing processes as a major activity to those performed by topping and cracking refineries.

(1.5) Integrated refinery (subcategory E) :

The integrated refinery (Fig. 7) includes all the major refinery operations: topping, cracking, lube oil manufacturing, and petrochemical processing.

Fig. 3

Topping Refinery



MEDIAN REFINERY FLOW SHEET

Fig. 4

Cracking Refinery

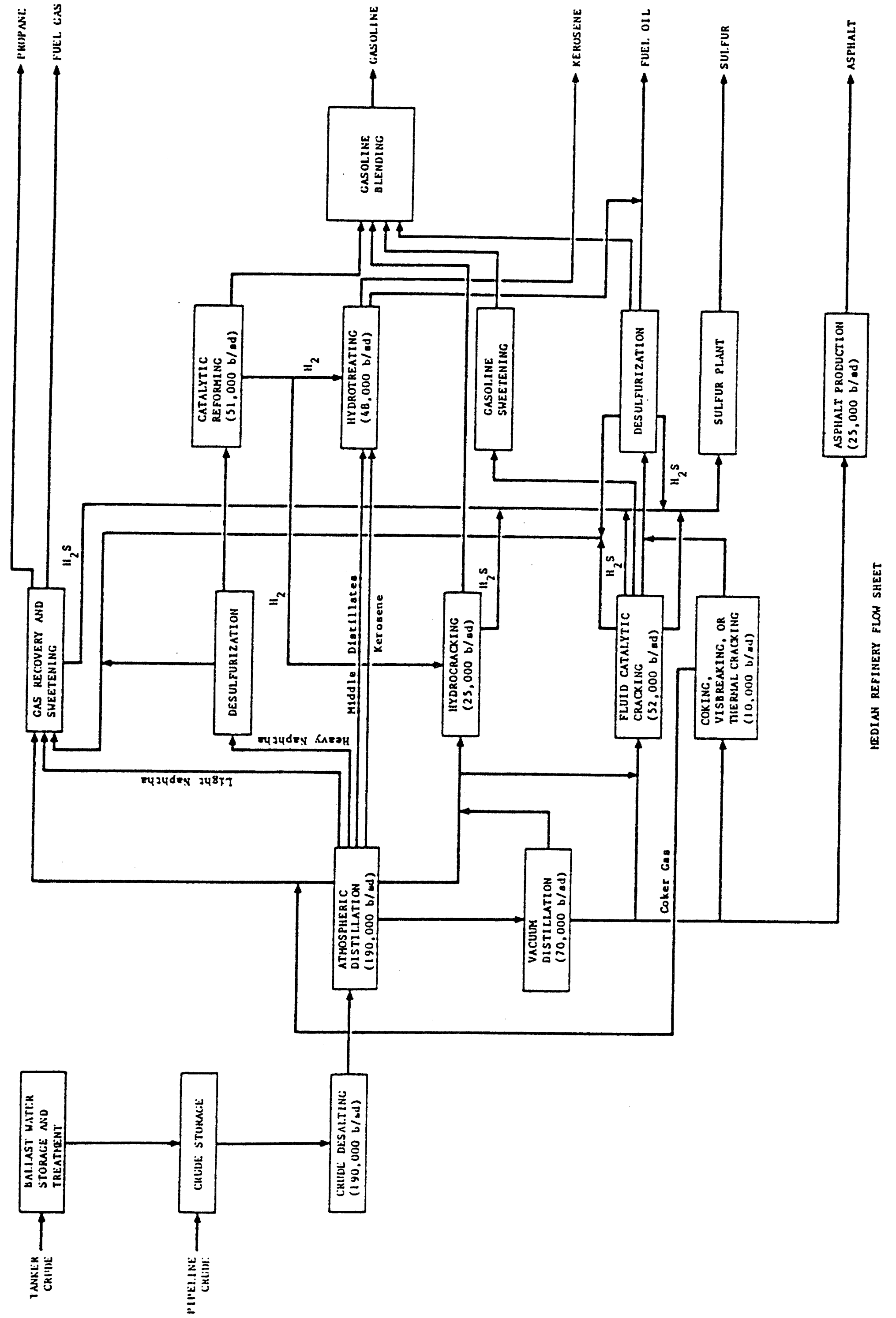


Fig. 5

Petrochemical Refinery

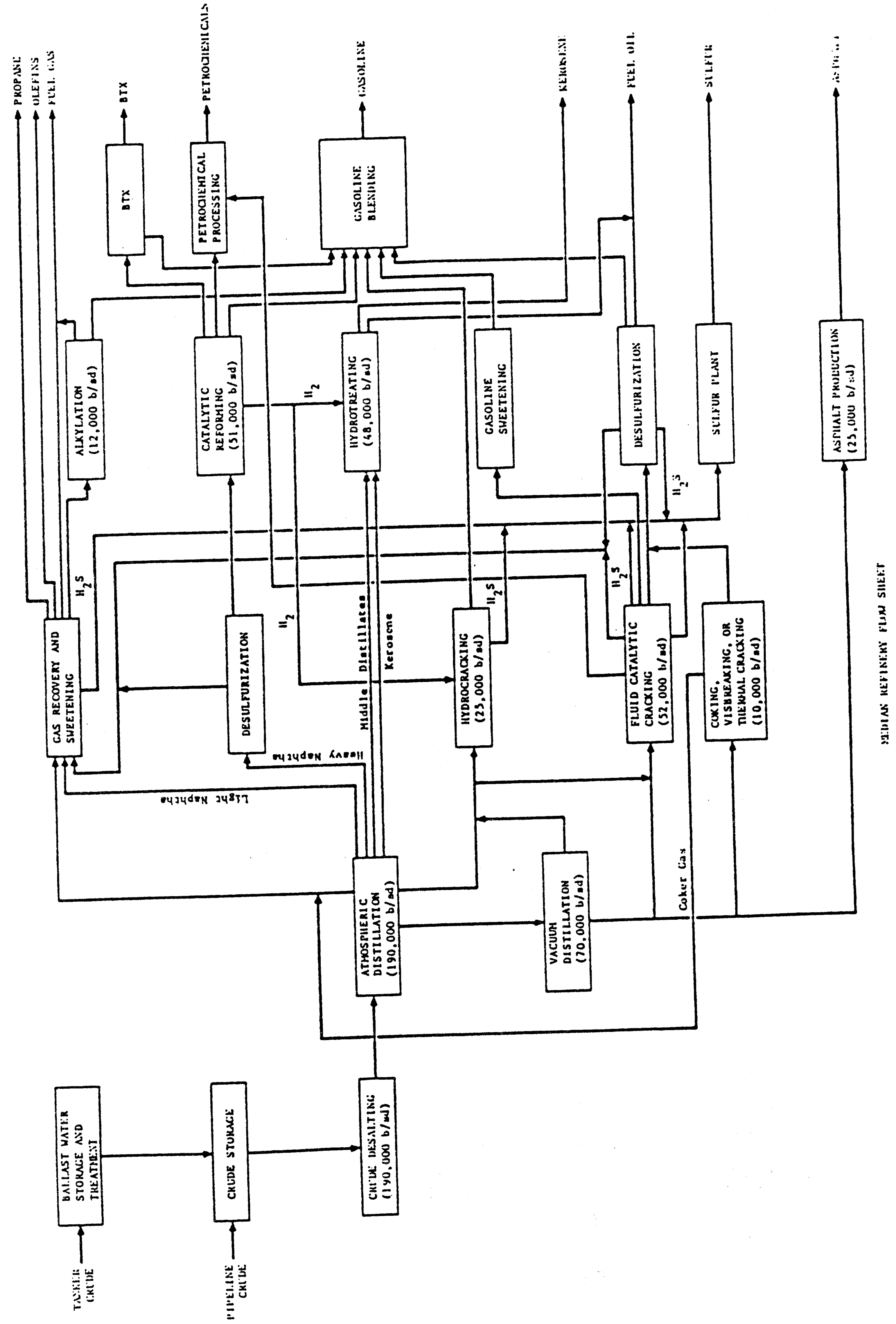
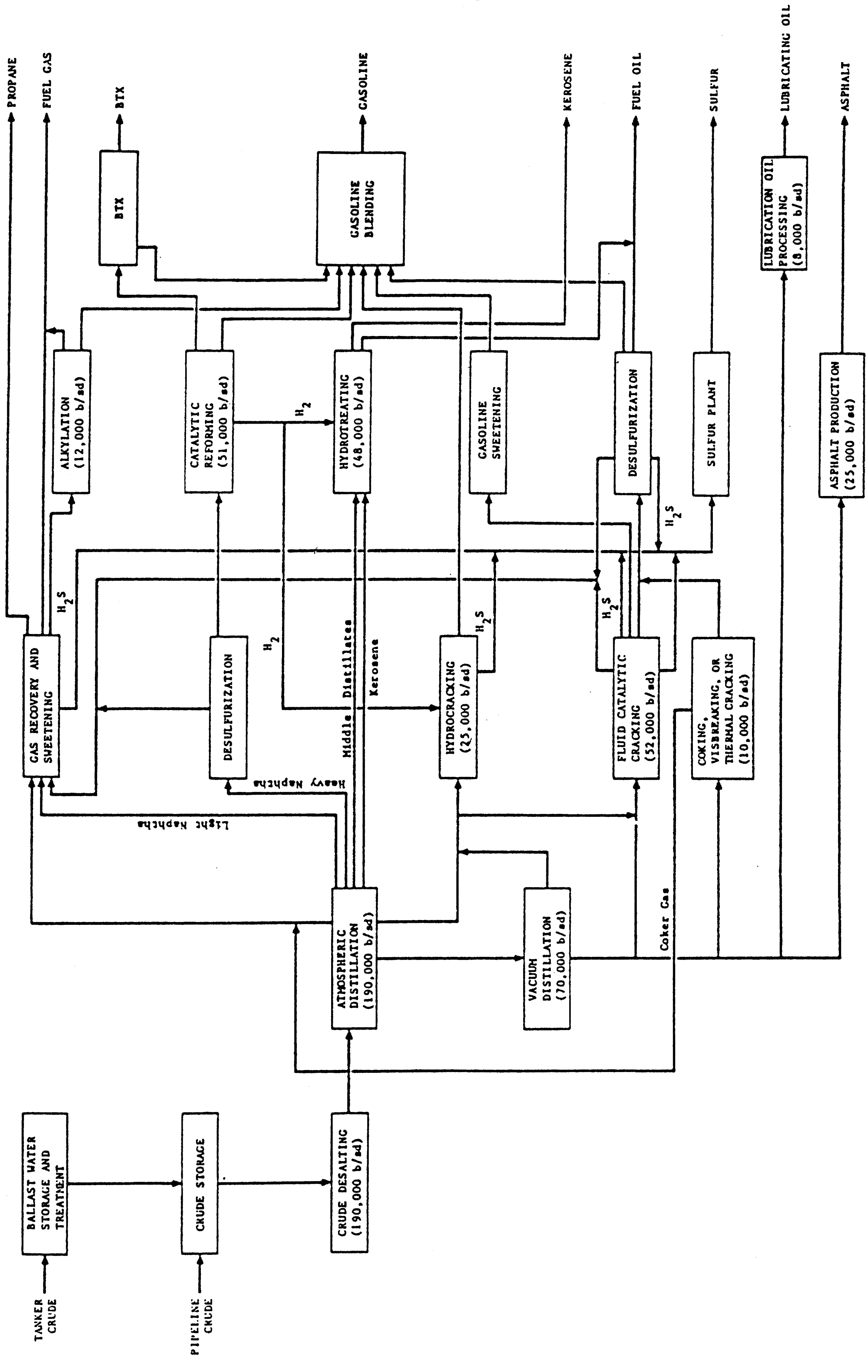


Fig. 6

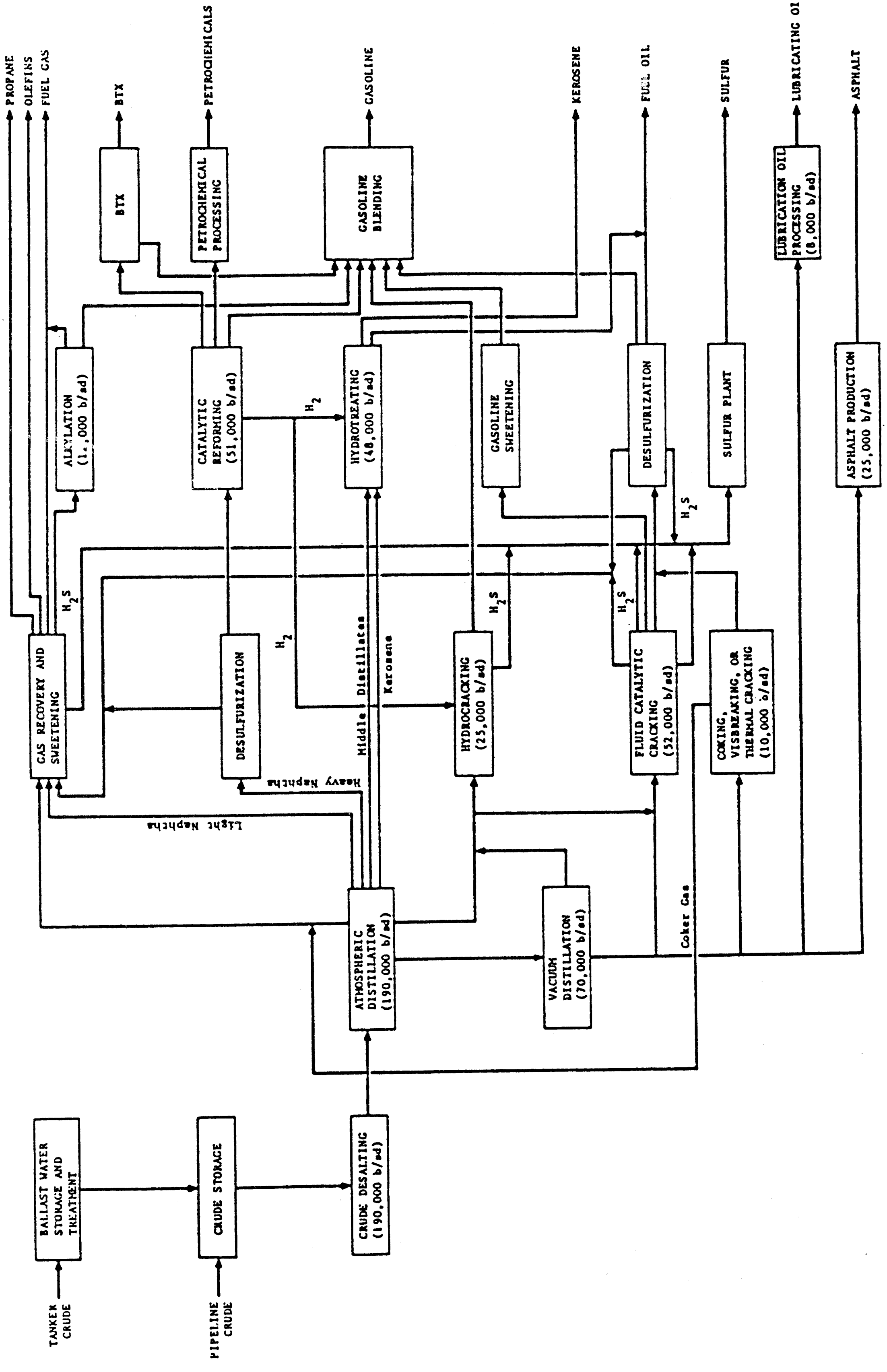
Lube Refinery



MEDIAN REFINERY FLOW SHEET

Fig. 7

Integrated Refinery



MEDIAN REFINERY FLOW SHEET

2. OIL REFINING PROCESSES AND TECHNOLOGY

The following is a brief description of the major refinery processes, and the pollution streams resulting from these processes.

(2.1) Crude Desalting :

Inorganic salts, water, suspended solids, and certain water soluble compounds must be removed from crude oils to prevent equipment fouling, corrosion, and catalyst poisoning in downstream processing units.

Crude desalting is essentially a solvent extraction process using water as the extraction medium. In chemical desalting, chemical de-emulsifiers (surfactants) are added to the crude oil, water is added, and the resulting emulsion is heated to 66-177 degrees C and held in a settling tank. Salts and other impurities dissolve in or attach to the water globules which settle out and coagulate. Electrical desalting differs from chemical desalting; electrical differentials are applied and de-emulsifiers are used only for crude oils with a high suspended solids content. Suspended water globules are concentrated in the bottom portion of the settling tank under the influence of a high voltage electrostatic field.

Approximately 35-60 litres of wastewater per each cubic metre of crude processed are discharged to the wastewater treatment or sewer system. The wastewater contains extracted chlorides, sulphides, bicarbonates, oil, ammonia, phenol, and suspended solids. This wastewater would cause adverse effects if discharged untreated into water bodies.

(2.2) Crude Oil Fractionation :

Crude oil is distilled using single or multiple fractionating columns and processes to separate it into intermediate product streams. Usually, crude oil is preheated, charged to an atmospheric fractionation (distillation) column at about 344-371 degrees C. The vaporized oil condenses in the vertical fractionation column, with lighter (higher boiling point) fractions diffusing and condensing toward the top of the column and heavier (lower boiling point) fractions condensing or remaining at the bottom. Fractions are continuously drawn off and diverted for further processing or distribution.

Residual, high boiling point materials are usually withdrawn into a vacuum fractionation column for separation into lubricants, residual oil fractions, and/or catalytic cracking feedstocks. Heavy asphalt residual base stock is withdrawn from the bottom of the column. Light fractions may be further fractionated and degassed to produce straight-run gasoline. Gases removed during fractionation include methane, ethane, propane and butane.

The waste streams consist of condensed water-containing sulphides in high concentrations when sour (high sulphur) crudes are processed. They are usually discharged to the wastewater treatment or sewer system. The wastewater also contains ammonia, phenols, oil, chlorides, thiols (mercaptans), and other water soluble compounds. Distillation is essentially a closed process, in terms of atmospheric releases. Fugitive hydrocarbon emissions and process heaters are the major sources of atmospheric emissions.

(2.3) Drying and Sweetening :

Sweetening processes remove sulphur compounds, primarily hydrogen sulphide, mercaptans, and thiophenes, to improve odour, colour, and oxidation stability; to lower fuel sulphur content to comply with environmental regulations; and to lower the amount of tetraethyl lead required to boost gasoline octane ratings. Drying removes water and both processes lower concentrations of carbon dioxide and other impurities.

Most sweetening processes involve the use of a caustic (basic) regenerable sorbent liquid, usually diethanolamine, to extract sulphur compounds. Washing solutions are regenerated by heating and air or steam stripping. Electrical fields may be applied to facilitate separation. Drying is performed using sand filters, absorptive clay beds, or other water adsorptive or absorptive media.

Spent caustic solutions are the most common wastes from drying and sweetening. Spent caustics may be characterized as sulphidic or phenolic, depending on the oil treated. Spent sulphidic caustics contain high sulphide concentrations. Spent phenolic caustics contain high concentrations of phenols, cresols, xylenols, and sulphur compounds. Spent caustics have very high BOD and COD. Sweetening of sour gases results in a hydrogen sulphide rich gas stream that may be flared, burned as fuel, or processed to recover elemental sulphur.

(2.4) Solvent Refining and Dewaxing :

Solvent refining includes a multitude of processes that extract desired and undesired components from feedstocks on the basis of differential solubilities. Most frequently, the processes are used to separate aromatic from non-aromatic components, dewax lubrication oils, deoil waxes, and to remove undesired unstable, acidic, sulphur, organometallic, naphthenic, and/or nitrogen compounds.

Solvents used in the various processes include acetone, benzene, dichloroethane, methyl-isobutyl ketone, pentane, propylene, toluene, water and others. The processing usually involves: drying and/or deaeration of the feedstock; using countercurrent solvent extraction techniques; separation of the bulk solvent from the product by heating and fractionation or evaporation; removal of solvent traces from the product by steam stripping or vacuum flashing; and solvent purification for reuse.

The solvents themselves are the major potential pollutants from solvent refining. Many of the solvents such as phenol, glycols, and amines have high BOD. Solvents are nearly always recycled, but leaks and spills may occur. Water from the bottom of fractionation towers containing oil and solvent is the main aqueous waste stream.

(2.5) Hydrotreating :

Hydrotreating involves the catalytic combination of hydrogen with feedstock hydrocarbons. Hydrotreated feedstocks may be used as blending stocks for final products, or they may be used as feedstocks for additional processing, especially catalytic reforming which requires hydrotreating as pretreatment to maintain catalyst viability and to yield a better product. Hydrotreating causes sulphur-bearing compounds to form hydrogen sulphide and nitrogen-bearing compounds to form ammonia. Approximately 90 per cent of the sulphur and nitrogen are removed from the feedstock. Catalyst regeneration associated with subsequent catalytic cracking will release less sulphur dioxide to the atmosphere.

The concentration and quantity of wastes depend on the process used. Wastewater streams come from steam strippers, sour water stripper bottoms, and accumulators on fractionation columns. Sulphides and ammonia are the major pollutants. Phenols may be present if a high boiling point feed is used.

(2.6) Hydrocracking :

Hydrocracking is probably one of the most economically important processes in modern refineries. Heavy sour feedstocks may be converted into sweeter, lighter, more profitable products, especially gasoline, other light fuels, and petrochemical feedstocks. Hydrocracking is much like hydrotreating, but takes place in a hydrogen atmosphere at higher pressures and lower temperatures. Reactor outputs are separated, and fractionated; hydrogen is recycled to the reactor, and heavier-than-desired fractions are recycled to the reactor. Olefins (alkenes) formed during cracking are saturated with hydrogen.

Aside from the process heaters, atmospheric emissions result from catalyst regeneration operations and fugitive hydrocarbon emissions. Large quantities of carbon monoxide may be released from catalyst regeneration. A sour water and ammonia-containing waste stream forms from steam condensation during catalyst steam stripping and regeneration. Catalysts usually have a life of about 2 years, after which they may be reclaimed or disposed of as solid waste.

(2.7) Alkylation :

Alkylation is used to convert normally gaseous hydrocarbons to high-octane gasoline components. A dry, olefinic feedstock is mixed with excess isobutane and reacted with an acid catalyst in a reaction vessel. The catalysts may be hydrofluoric acid, aluminium chloride, or sulphuric acid. Reactor output is separated, the acid phase recycled to the reactor, and hydrocarbons are passed through a caustic and water wash and fractionated. Excess isobutane is recycled to the reactor and by-products (normal butane and propane) are removed.

Catalytic alkylation processes are generally closed systems with no process vents to the atmosphere, except for those from fired heaters. Hydrofluoric acid units are generally closed systems. However, any leaks or spills involving fluorides are hazardous to health and environment. Alkaline scrubbers remove any fluorides that could be incidentally discharged in process streams. HF acid regeneration units usually produce a sludge material that is either incinerated or alkaline washed to produce solid waste fluorides. Fluorides removed from the output are also disposed of as solid wastes.

Wastewaters from sulphuric acid process product scrubbing are usually processed by the refinery's water neutralization and wastewater treatment systems to recover the acid or to neutralize other wastes. Waste streams from scrubbing usually contain sulphides, suspended and dissolved solids, oils, and other contaminants.

(2.8) Isomerization:

Isomerization is used to convert normal C4 to C6 primary alkanes (butane, pentane, and hexane) into their respective isopraffins (secondary alkanes). Sweet, dry feedstock is mixed with hydrogen and organic chlorides as a promoter; then it is heated, and passed over a catalyst. Hydrogen is separated from the product and recycled, Liquids are fractionated to separate normal paraffins from isoparaffins and isoparaffin product streams are neutralized with alkaline materials. Normal paraffins are recycled, isobutane is sent on to alkylation units, and isopentane and isohexane are used for gasoline blending. Hydrogen is used in the process to hydrogenate side-reaction unsaturated compounds and to prevent polymerization.

Isomerization is essentially a closed process. The neutralization step produces some aqueous wastes that would probably be relatively low in sulphide, ammonia, phenolics, and BOD. Catalysts are generally replaced after 2 years and reprocessed for platinum and precious metal recovery at plants that are separate from the refinery.

(2.9) Catalytic Reforming :

Reforming is primarily used to increase the octane rating or antiknock qualities of naphtha-rich fractions used as gasoline blending stock. Although a number of reactions take place, the predominant reactions are the dehydrogenation and aromatization of naphthenes (cyclic alkenes) to form stable C6 to C8 aromatics, such as benzene, toluene, xylenes, and others.

Platforming is the most widely used catalytic reforming process. The charge and recycled gases are heated and passed through a series of catalytic reactors. Reactor output is separated into liquid and gas streams, the gases are compressed for recycling, and liquids are stabilized to the desired vapour pressure. Catalysts may be continuously withdrawn, regenerated, and returned to the top of the reactor units. Alternatively, the catalyst may be periodically regenerated by taking the reforming units off stream, or one reactor may be regenerated at a time.

Catalytic reforming is essentially a closed system process. Slight atmospheric emissions may occur from catalyst regeneration, mostly as carbon monoxide.

(2.10) Thermal Cracking :

Thermal cracking involves the breaking down of heavy oil fractions, usually residuals from vacuum fractionation processes, into lighter (lower-molecular weight) middle distillate and heavy fuel oil fractions.

Visbreaking is a mild form of thermal cracking that causes little reduction in boiling point range, but significantly lowers the viscosity of the feed. The feed is heated in the visbreaking heater, vapours are removed, and the heavier fractions are recycled. The output may be fractionated for gasoline, fuel oils, gas oil, and gases.

Coking is a severe form of thermal cracking, often using a residual feedstock that has resisted other cracking processes. Feed is heated and held at a high temperature. The vapour phase undergoes further cracking, and the liquid phase undergoes successive cracking and polymerization to form vapours and coke. Vapour phases are fed into fractionation units.

Water, usually containing various oil fractions and high in BOD, COD, ammonia, phenol and sulphides, results from thermal cracking fractionation units. Wastewater may be highly alkaline.

(2.11) Catalytic Cracking :

Catalytic cracking is used to increase the yield and quantity of gasoline and other desirable lighter products, while minimizing the yield of residual or heavier products. Catalytic cracking involves the use of at least four chemical reactions-thermal decomposition, primary catalytic reactions at the catalyst surface, secondary catalytic reactions between the primary products, and polymerization and removal of products from reactions by absorption on catalyst surfaces as coke.

Catalytic cracking is a major source of refinery pollution. Catalyst regeneration, involving steam stripping and decoking, results in fluid waste streams containing oil, sulphides, phenols, ammonia, and other substances. The catalyst steam stripper uses about 120 litres of water per 1 cubic metre of feed, which is routed to wastewater treatment systems. Atmospheric emissions from generators include particulates, sulphur oxides, carbon monoxide, hydrocarbons, nitrogen oxides, aldehydes and ammonia.

(2.12) Polymerization :

Polymerization is used to convert olefin (alkene) feedstocks into higher-octane gasoline blends. Polymerization is much like catalytic alkylation. However, two olefins are combined, rather than an olefin and an isoparaffin, as in alkylation. Polymerization is decreasing in use because olefins yield a higher return when used as feedstocks for petrochemicals.

Polymerization is a closed process with no marked atmospheric emissions. Alkaline solutions from caustic washing and acids washed out during maintenance are liquid wastes. Acid catalysts adhering to solids yield solid waste when periodically removed.

(2.13) Deasphalting :

Deasphalting, or the removal of asphalt residues, is used to upgrade several intermediates and products. Deasphalting improves lubricating oil qualities and deasphaltized oils are among preferred feedstocks for catalytic cracking and hydrocracking processes. Extracted asphalt may be utilized by blending with other products or the asphalt output may be marketed. Deasphalting removes some sulphur and nitrogen compounds, metals, carbon residues, and paraffins from the feedstock.

Atmospheric emissions are process heater flue gases and fugitive emissions from high-pressure equipment. Condensed steam contaminated with hydrocarbons is usually routed to the refinery wastewater treatment facility.

(2.14) Asphalt Blowing :

Asphalt blowing oxidizes asphalt hydrocarbons, increases their melting temperature, hardness, and weathering properties. Asphalt is batch heated and air is blown through it. Exothermic oxidation reactions proceed without additional heat input. Reaction conditions foster the development of polycyclic aromatic hydrocarbons (PAHs), many of which are carcinogenic.

Vented gases constitute one of the more objectionable forms of air pollution from a refinery. They have highly objectionable odours and contain a large proportion of the polycyclic aromatic hydrocarbons.

(2.15) Grease Manufacture :

Grease primarily consists of mixtures of soaps and lubrication oils. The properties of a grease are largely determined by its soap component. Soaps are manufactured at the refinery or purchased as raw materials.

Aqueous effluent results when process units are washed and soaps and oil are discharged to a sewer or wastewater treatment system.

(2.16) Wax Manufacture :

Paraffin and microcrystalline waxes with low oil content, high melting point, and other desired properties are manufactured.

Wax manufacture is not a significant source of wastes. Solvents and oil may enter wastewater systems through leakage. Wax in sewer systems may interfere with settling operations in wastewater treatment plants and may clog sewers.

(2.17) Hydrogen Manufacture :

Several refinery processes, such as hydrotreating, hydrocracking, and associated petrochemical processes, require hydrogen feedstocks. Hydrogen by-products from catalytic reforming frequently do not satisfy a refinery's need for hydrogen.

Steam reforming, the most widely used process, involves the mixing of sweetened gases with superheated steam and the charging of the mixture to a hydrogen furnace consisting of a vertical combustion chamber with suspended alloy tubes containing a nickel-based catalyst. Hydrocarbons are catalyzed to hydrogen, carbon dioxide, and carbon monoxide.

Few wastes occur from hydrogen manufacture. Free carbon removed from a water wash associated with the partial oxidation process may be a minor waste.

(2.18) Process Heaters and Steam Production :

Process heaters are used throughout the refinery to heat feedstocks to reaction temperatures and for distillation. Steam is produced in one or more units for direct use in various processes, for heating, and to drive equipment. Steam generation units may be used to recover waste heat and for cooling.

For residual oil-fired and gas-fired boilers, emissions consist mainly of particulate matter, sulphur oxides, nitrogen oxides, carbon monoxide, and hydrocarbons. Oil-fired boilers emit more of these emissions than gas-fired ones. Aqueous wastes associated with steam production are primarily boiler blowdown, which usually has low oil and phenols concentration and is often reused in other process units with minimal treatment. Solid wastes include ash from boilers and sludges from treatment of steam boiler feed water.

(2.19) Crude Oil and Product Storage :

Crude oils are stored to provide adequate feedstocks for economical use of refining facilities. Storage of intermediate products equalizes material flows within the refinery. Final products storage is used to store finished products prior to shipment, to mix and blend products, and to lessen the effects of product demands on refinery operations.

Crude oil and intermediate and final products are stored in steel tanks ranging in size from several thousand barrels to several hundred thousand barrels capacity. Settled water and suspended solids are drawn off periodically. Many tank storage systems employ methods to minimize releases of hydrocarbon vapours such as floating-roof tank covers, tank pressurization, and/or connections to vapour recovery systems.

Free and emulsified oil, as well as water and suspended solids, are drawn off into the wastewater treatment system. Bottom sludge and sediments are removed less frequently and are generally disposed of in landfills or by landspreading. Leaks, spills, and tank cleaning produce additional wastes. Intermediate storage may be a source of polysulphide-bearing wastewater and iron sulphide suspended solids. Final product storage wastewaters may contain tetraethyl lead and other additives.

(2.20) Wastewater Treatment :

Wastewater treatment is used to upgrade used process, runoff, and sewerage waters prior to their discharge into open waters, publically owned treatment works, or their reuse within the refinery. Refinery wastewaters typically contain oil, grease, dissolved and suspended solids,phenolic compounds, ammonia, chromium, sulphides, and other compounds for which effluent levels have been set by laws. Some refineries totally recycle their process water. In general wastewaters are subjected to primary, secondary and tertiary treatment (Fig.8). The final effluent disposal is accomplished by direct discharge, controlled discharge from holding ponds, or eventual discharge from a series of aerated lagoons.

Atmospheric emissions consist primarily of hydrocarbons released from the collection system and primary treatment units. The latter produce solid wastes in the form of dirt, grit, oily sludges, and clarifier sludges. Secondary treatment produces bacterial sludges. These solid wastes are usually landfilled or landspread. Bacterial sludges my be incinerated and the resulting ash landfilled.

3. EMISSIONS AND WASTES FROM OIL REFINERIES

3.1 Airborne Emissions

Air emissions vary greatly among refineries. Factors such as crude feedstocks, processes, equipment, air pollution control measures, housekeeping and maintenance practices, and the age and type of refinery strongly influence the amount and kinds of refinery released air pollutants. Table 7 summarizes the potential sources of the main air emissions from oil refineries.

Fig. 8

Wastewater Treatment in Refineries

OPTIONAL REFINERY TREATMENT SEQUENCE

Treatment	Pre-or Inplant Treatment	Primary Treatment	Intermediate Treatment	Secondary Treatment	Tertiary Treatment
Objectives	Phenolics, $S^=$, NH^3, RSH, F^-, Acid Sludge, Oil Etc., Removal & Water Reuse or Waste Equalization	Free Oil and Suspended Solids Removal	Emulsified Oil, Suspended and Colloidal Solids Removal	Dissolved Organics Removal	Variable Objectives
Processes	Unit Separators	API Separators	Chem. Coagulation & Air Flotation	Trickling Filter	Chem. Coagulation & Air Flotation
	Steam Stripping	CPI, PPI Separators	Chem. Coagulation & Filtration	Activated Sludge	Chem. Coagulation & Filtration
	Fuel Gas Stripping		pH Control	Oxidation Pond	Activated Carbon
	Air Oxidation		Immediate Oxygen Demand Reduction	Aerated Lagoon	
	Neutralization		Equalization of Wastes		
	Surge Ponds	↓ Sludges	↓ Sludges	↓ Sludges	↓ Sludges

Air pollutants from oil refineries disperse in much the same way as other industrial airborne emissions. Concentrations of pollutants in the plant's immediate vicinity depend on the spatial distribution and physical characteristics of the emission sources. Combustion source stack emission height and emission temperature affect local ground concentrations of emissions- higher stacks and hotter emissions generally lead to lower ground concentrations. The trend toward maximum heat recovery may be lowering the temperatures of stack emissions and exacerbating combustion-related ground levels of pollutants. Fugitive emissions generally occur near ground level and, thus, may pose hazards to employees and those in the immediate area.

Meteorological factors are the primary determinants influencing dispersion of air pollutants. Concentrations of air pollutants are functions of dilution and diffusion processes. These depend largely on interrelated meteorological factors, such as atmospheric stability, wind speed and direction, mixing depth, temperature, humidity, precipitation, and inversions.

Table 7 Sources of Air Emissions from Oil Refineries

Emissions	Sources
Sulphur oxides	Boilers, process heaters, catalytic cracking unit, regenerators, treating units, hydrogen sulphide flares, decoking operations.
Hydrocarbons	Loading facilities, turn-arounds, sampling, storage tanks, wastewater separators, blowdown systems, catalyst regenerators, pumps, valves, blind changing, cooling towers, vacuum jets, barometric condensers, air-blowing, high pressure equipment handling volatile hydrocarbons, process heaters, boilers, compressor engines, distillation towers, separators.
Nitrogen oxides	Process heaters, boilers, compressor engines, catalyst regenerators, flares.
Particulate matter	Catalyst regenerators, boilers, process heaters, decoking operations, incinerators, flares.
Aldehydes	Catalyst regenerators.
Ammonia	Catalyst regenerators.
Odours	Treating units (air-blowing, steam-blowing) drains, tank vents, barometric condenser stumps, wastewater separators, process vessels.
Carbon monoxides	Catalyst regeneration, decoking, compressor engines, incinerators, boilers, flares.

Source : UNEP (1987)

2. Wastewater

A refinery generates a variety of wastewaters, as a result of various processes. Major waste streams include sour water or condensates, cooling tower blowdown, boiler blowdown, storm water, ballast water, tank water bottoms, caustic scrubs, and crude desalter water. Most refineries apply primary and secondary wastewater treatment processes to their wastewater streams. Since it is a typical practice in refineries to collect all or several contaminated wastewater streams and combine them for treatment and disposal, it is difficult to deal with the volumes and contents of individual process-related wastewater effluent streams. Table 8 summarizes the wastewater pollutant sources in oil refineries. Table 9 gives the composition of raw waste produced from different categories of refineries (90% probability of occurrence).

Table 8 Wastewater Pollutant Sources in Oil Refineries

Pollutant	Sources
BOD5, COD, Oil	Process water Cooling tower blowdown Ballast water Tank flow drainage and runoff
Total suspended solids	Process wastewater Cooling tower blowdown Ballast water Tank flow drainage and runoff
Phenolics	Process wastewater
Ammonia, hydrogen sulphide, organics	Process wastewater
Heavy metals	Process wastewaters, Tank wastewater discharges Cooling tower blowdown.

Source : UNEP (1987)

Studies have shown that more than 370 organic substances have been identified in refinery effluents (see, for example, Thoman and Hushon, 1979). Many of these compounds are considered to be carcinogens based on animal and human tests. Others are highly toxic or pose unknown toxic hazards. For regulatory purposes, focus has been made on some parameters; the US EPA lists 129 substances on its Priority Pollutant List.

Table 9 Raw waste from different refineries*

Pollutant	Topping	Cracking	Petrochemical	Lube	Integrated
BOD5	217	466	715	758	615
COD	486	2517	1087	2288	1487
TOC	66	320	458	386	678
TSS	286	361	371	312	225
Oil & grease	89	364	234	601	269
Phenols	1	81	24	53	23
Ammonia	19	175	206	96	122
Sulphides	2	39	92	20	8
Chromium	0.3	4	4	1	2
Flow **	558	2746	443	772	1373

* kg/1000 cubic m of feedstock throughput
** 1000 cubic m/ 1000 cubic m of feedstock throughput
Source : US Environmental Protection Agency (1982).

3. Solid Wastes

Refineries typically produce a number of process-related solid wastes, including: crude oil tank bottoms; leaded gasoline tank bottoms; oil-water separator sludge; neutralized hydrofluoric acid alkylation sludge; kerosene filter clays; cooling water sludge; dissolved air floatation skimmings; spent lime from boiler feedwater treatment; spent amine solids; exchanger cleaning sludge; waste biological processing sludge; silt from stormwater runoff; fluid catalytic cracker catalyst fines; coke fines; lube oil filter clays; spent catalysts; chemical precipitation sludges; vacuum or centrifuge filtration sludge; and silica gel and other filtration media.

The first 13 wastes listed above are typically produced by topping and all other types of refineries. Cracking, petrochemical, and integrated refineries also generate fluid catalytic cracking fines and coke fines. Lube refineries generate lubricating oil filter clay wastes. Spent metallic catalysts may not be refinery wastes, for many undergo off-site reprocessing to recover their metals content. Chemical precipitation sludges, silica gel, and other filtration media will usually be waste products from refineries with tertiary wastewater treatment systems.

A number of variables affect the composition and quantities of wastes produced by a refinery. One of the major variables is the crude oil feedstock. Crude oil heavy metals content will significantly affect the metals content of crude oil storage tank bottoms and a number of other wastes. Another set of variables involves the mix of processes performed at the refinery. For example, hydrofluoric acid and sulphur acid alkylation units generate distinctly different wastes. As noted above, the processes used at refineries vary greatly. This contributes to a wide variation in the quantity and constituents of wastes among refineries.

Current final disposal technologies of refinery solid wastes include on-site or off-site landfilling, landfarming, and to a lesser extent, incineration, deep well and salt mine disposal, ocean dumping, and lagooning.

4. Pollution Reduction

4.1 Air Emissions :

Air emissions vary significantly, both in quantity and type, among refineries and their effect on the environment will vary. Among the factors that affect the amount and typpe of refinery air emissions are : crude feedstocks, processes, types of equipment, air pollution control measures, housekeeping, maintenance practices and the age and category of refining. Air emissions occur from a multitude of specific sources and are usually handled separately. Thus, air pollution control systems, when used, are associated with specific process units and are usually designed to remove or modify specific contaminants. The main areas that could contribute to pollution reduction include changes in design and operating procedures, housekeeping, and introduction of new techniques. Table 10 gives examples of control measures to reduce air emissions from oil refineries (Mallatt, 1977; Galue, 1985; Labuda, 1985; UNEP, 1987).

One of the most difficult air pollution problems is that caused by sulphur. Several improved processes have been introduced to deal with this problem, for example, the Claus unit tail gas treatment. This includes wet processes (e.g. the Clauspol 150 process) and the dry processes (e.g. the Sulfreen process). Several other technologies are available for removing sulphur oxides from stack gases (Coupard and Hournac, 1985). The selection of the appropriate technology will depend on local conditions and on cost.

Al-Shehri et al. (1994) reviewed the potential for energy conservation in oil refineries. They pointed out that operating improvements and maintenance and mechanical improvements can contribute to marked reduction of energy use in refineries. They outlined 25 measures that would contribute to about 20% overall energy savings in SAMAREC refineries in Saudi Arabia. A large number of these measures have been implemented. This reduction in energy use in oil refineries would also lead to marked reduction in air emissions from the refineries.

Table 10 Control Measures for Reduction of Air Contaminants from Oil Refineries

Source	Control method
Storage vessels	vapour recovery systems, floating roof tanks, pressure tanks, vapour balance.
Refinery process gas	Ethanolamine absorption
Accumulator vents	Vapour recovery
Blowdown systems	Smokeless flare-gas recovery
Pumps and compressors	Mechanical seals, vapour recovery, sealing glands by oil pressure, maintenance
Equipment valves	Inspection and maintenance
Pressure relief valves	Vapour recovery, rupture discs, inspection and maintenance
Effluent waste disposal	Enclosure of separators, covering of sewer boxes and use of liquid seal, liquid seals on drains.
Bulk loading facilities	Vapour collection with recovery, submerged or bottom loading
Acid treating	Continuous-type agitators with mechanical mixing, replacement with catalytic hydrogenation units, cessation of sludge burning.
Acid sludge storage and shipping	Caustic scrubbing, vapour return system.
Spent caustic handling	Scrubbing, neutralization.
Sour water treating	Use of sour water oxidizers, conversion to ammonium sulphate.
Mercaptan disposal	Conversion to disulphides, adding to catalytic cracking change stock, use of material in organic synthesis.

Odours are common in oil refineries. The processing units which may emit odours include catalytic cracking, asphalt production, lubricating oil treatment, and sulphur recovery units. Also, any open stirring, venting, or flaring is liable to create odour emissions. Absorption and combustion are the most commonly used odour control methods and include: aldehyde absorption in bisulphite solutions; thiols absorption in sodium hydroxide solutions; hydrogen sulphide absorption in amine solutions, activated carbon, active manganese dioxide, and on sawdust. Masking agents and odour counteractants may be used to cover up odours.

4.2 Wastewater

In-plant source control reduces the overall pollutant load that must be treated by an end-of-pipe system and reduces or eliminates a particular pollutant before it is diluted in the main wastewater stream. In developing an in-plant control scheme, the source of each particular pollutant must be identified and evaluated as to whether it can be eliminated or reduced. Sampling the wastewater at various points within the refinery sewer, beginning at the end-of-pipe treatment system and ending at the process units, produces a profile of the refinery sewer, which shows the origin and flow path of the pollutant in question. Once the source of the particular pollutant is identified, the next step is to determine if the pollutant can be (a) removed within an in-plant treatment system; (b) eliminated by chemical substitution; or (c) reduced by recycling or reusing the particular wastewater stream (EPA, 1982).

Reduction in water usage may sometimes be more cost-effective if the wastewater discharge is reduced, rather than reusing or recycling the existing amount of wastewater discharged. Some of the refinery design modifications that would contribute to reduced water use include :

- Substitution of improved catalysts that require less regeneration.
- Replacement of barometric condensers with surface condensers or air fan coolers.
- Replacement of surface condensers with air fan coolers.
- Use of hydrocracking and hydrotreating processes that produce lower wastewater loadings than existing processes.
- Increased use of improved drying, sweetening, and finishing procedures to minimize spent caustics and acids, water washes, and filter solids requiring disposal.
- Recycle of wastewater at the process units to reduce the amount of wastewater leaving the process area.

A major process change than can reduce wastewater is the substitution of air cooling devices for water cooling systems. Many refineries have installed air cooling systems with their new process installations, thereby reducing the additional wastewater production associated with increased refinery complexity.

Wastewaters emanating from end-of-pipe facilities are generally of such quality that reuse can be quite attractive. Uses for treated refinery wastewaters include makeup water for cooling towers, pump gland cooling systems, washdown water, and fire water systems. The American Petroleum Institute concluded that for most existing refineries engineering concepts are available which indicate complete reuse of refinery water is technically possible and that the capital and operating costs appear favourable for complete recycle.

4.3 Solid Wastes

Refinery process solid wastes can be divided into two types: intermittent and continuous (UNEP, 1987). Intermittent process wastes are those which generally result from the cleaning of refinery facilities and which require disposal at intervals greater than two weeks. Typical examples of these wastes are (a) storage tank bottoms, leaded and unleaded; (b) process vessel sludges, vessel scale and deposits generally removed during plant turnarounds; and (c) product treatment facilities wastes, such as spent filter clays and spent catalyst from units such as the reformer, hydrodesulphurizer, etc. Continuous process wastes result from wastewater treatment processes and from manufacturing process units and normally require disposal at intervals of less than two weeks. Typical examples of wastewater treatment wastes are (a) waste biosludge; (b) separator sludge; (c) dissolved air floatation float; (d) centrifuge cake and (e) vacuum filter cake. Typical of manufacturing process unit wastes are (a) spent catalysts and catalyst fines from the fluid catalytic cracking unit;

(b) coker wastes, such as coke fines from the delayed or fluidized coker and spilled coke from the unloading facilities; and (c) spilled grease and wax from the lube oil processing plants.

Waste reduction involves the process to reduce the amount of waste material produced. Methods include new processes, treatment, use of different catalysts or chemicals, water reuse, and better process control.

Land treatment systems have been used for the treatment of petroleum industry wastes for many years. Land treatment is a managed technology that involves the controlled application of a waste on the soil surface and the incorporation of the waste into the upper soil zone. It is not the indiscriminate dumping of waste on land. Land treatment waste management technology relies on the dynamic physical, chemical, and biological process occurring in the soil. As a result, the constituents in the applied wastes are degraded,immobilized, or transformed to environmentally acceptable components. Land farming - a new biological approach-show great promise, and several experiments have been carried out using refinery sludges to improve soil fertility (Coupard and Hournac, 1985). This may provide a beneficial use of such sludges in the ESCWA countries, specially in the arid and semi-arid desert areas of the Gulf.

CHAPTER 5

NATURAL GAS PROCESSING

Natural gas is composed chiefly of paraffin series hydrocarbons from C1 through C5 (mainly methane, ethane, propane, butane and pentane). The gas withdrawn from underground reservoirs carries with it lighter components vaporized from the crude oil with which it has been in contact. The composition of the natural gas liquids obtained by condensing these components is determined in large degree by the composition of the crude. Natural gasoline (also known as casing-head gasoline) was one of earliest components separated from natural gas. Because of the demand for this gasoline and other components of the natural gas liquids, essentially all natural gas is stripped of its condensable material. The individual components are separated by refrigerated absorption, low-temperature distillation, adsorption, or by membrane separation processes [2].

5.1 Liquefaction of Natural Gas :

The liquefaction of natural gas reduces its volume by hundreds of times and allows for efficiency in storage, transportation and handling. Natural gas is normally liquefied at -162 degrees C to obtain a 600 : 1 volume reduction.

Before liquefaction, the natural gas must be dried, heavier hydrocarbons fractions removed and pre-treated to remove such components as hydrogen sulphide, carbon dioxide and organic sulphur compounds that would solidify during liquefaction.

The two principal methods used for liquefaction are the cascade cycle and the expander cycle. The cascade cycle uses a series of refrigerants to sequentially lower the temperature. The refrigerants are usually liquid propane or ammonia, ethane or ethylene, and methane. Usually propane is used first to decrease the temperature to about -35 to -42 degrees C. The second stage uses ethane or ethylene to decrease the temperature further to about -97 to -100. The final stage reduces the temperature to at least -161 degrees C by means of methane-cooled heat exchangers.

The expander cycle is based on the concept of self-refrigeration as gas expands during a large pressure drop. When compressed gas passes through an engine it expands, resulting in a lowering of the temperature of the gas. This method of liquefaction is ideal for use in peak-shaving plants at the end of high pressure transmission lines where a large volume of gas needs to be depressurized before

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[2]. For areas not conveniently adjacent to gas lines, compressed gas in cylinders, the so-called bottle gas, makes excellent and convient fuel. The separated propane and butane are the main gases compressed. These liquefied petroleum gases (LPGs) are sold for domestic fuel and also as efficient motor fuel.

entering distribution mains. It is not as useful for baseload export-import systems.

The main environmental effects of a natural gas liquefaction plant are: discharge of heat to the atmosphere or to fresh or marine waters, depending on the type of cooling system used; and occasional emission or flaring of excess components of gas.

A significant environmental issue related to the use of cooling water within an LNG liquefaction facility is the entrainment of all pelagic/planktonic organisms and other smaller organisms not capable of avoiding or swimming against the intake current. For large facilities, entrainment may result in the deaths of 100 per cent of all living organisms entering the plant. A 100 per cent mortality rate, coupled with the tremendous volumes of water used, can result in heavy losses of phytoplankton and zooplankton, along with the egg, larvae, and juvenile stages of larger organisms in the surface water used as a water supply, especially if a large portion of the body of water passes through the plant within a short period of time.

There are also several environmental problems related to the once-through cooling system outside of the LNG facility. These include: impingement of larvae and juvenile organisms on traveling screens at intake; release of chlorine from compounds used as biocides within the cooling system; thermal pollution; and possible release of heavy metals resulting from the corrosion of the seawater exchangers which utilize aluminium brass for exchange tubes.

5.2 LNG Storage and Transportation :

LNG is usually stored in above-ground, double -walled metal tanks prior to transfer to tankers or to regasification facilities. For domestic purposes or for transportation over short distances, LNG is usually regasified before it is transported by pipelines. LNG regasification facilities vaporize the liquid by passing it through heat exchangers. These are heated by air or water at ambient temperature. Regasification occurs at pressures of up to 1,200 psig (pounds per square inch above atmospheric pressure), which are sufficient for input of the gas into a conventional natural gas pipeline.

Long-haul transportation of LNG is carried out by special tankers. The capacity of LNG tanker fleet has considerably increased since 1970, and approaches now some 10 million cubic metres.

Liquefied natural gas consists mainly of methane and there is a possibility of an explosive evaporation if the LNG comes into contact with the water. There is also the tendency of stratification if two LNG different in composition are mixed, for example, in storage tanks. In such cases, an increase of pressure inside the storage tank might occur and lead to an explosion if safety measures are not adequately taken.

If LNG is spilled, it boils rapidly. Although the vapour is not toxic, it may in high concentration cause asphyxiation by excluding oxygen. Moreover, the low temperature of the material may result in frostbite for anyone in the immediate vicinity of a spill. Little is known about the biological effects of LNG when spilled in the sea.

CHAPTER 6

USE OF OIL PRODUCTS AND NATURAL GAS

The final stages of the oil and natural gas fuel cycles are the end uses of the different products. This chapter deals with oil products and natural gas used for energy in stationary and mobile combustion processes. The chapter does not deal with the use of products used as feedstock for other industries. Such industries (e.g. the fertilizer industry, plastics..etc) are considered as separate industries in the UN Index to the Standard Industrial Classification (ISIC).[3]

Petroleum fuels are essentially mixtures of various hydrocarbons and different additives intended to improve quality or to counteract and reduce hazards associated with some of the hydrocarbons and their impurities. Because petroleum fuels are refined - or distilled from a broad range of feedstocks- they may be categorized by their end uses. The main petroleum fuels are : gasoline, diesel fuels, jet fuels and fuel oils. The first three are mainly used in mobile combustion processes, whereas fuel oils are mainly used in stationary sources. Fuel oils are broadly classified into two main types: distillate and residual. Distillate oils are used mainly in domestic and small commercial applications, whereas residual oils are used in utilities, industries and large commercial facilities.

The combustion of petroleum fuels and natural gas in stationary and mobile sources results in emissions of sulphur oxides, nitrogen oxides, particulate matter, carbon monoxide, hydrocarbons, trace metals..etc; with the quantity of pollutants dependent on the composition of the fuel used, the combustion process, and the extent of combustion. Tables 11 and 12 give estimates of pollutants emitted from the main stationary sources. The tables indicate that natural gas is a cleaner fuel than oil. The latter is still cleaner than coal. For example, on the basis of unit energy, the combustion of coal leads to the emission of 720 mg of sulphur dioxide/MJ, whereas fuel oil leds to the emission of 480 mg/MJ, and natural gas to 0.73 mg/MJ (OECD, 1988).

On a global basis, fossil fuels (coal, oil, natural gas) combustion accounts for the release of about 90 per cent of global anthropogenic sulphur oxides, 85 per cent of nitrogen oxides, 60 per cent of carbon monoxide, 40 per cent of particulate matter, 55 per cent of volatile organic compounds, 15-40 per cent of methane, and 55-80 per

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[3] It is difficult now to define "petrochemicals". Previously, there were identified as relatively pure substances derived from petroleum and used in the chemical trade. Now conversion processes are often built in as part of separation processes making original products more complex. Oil companies are entering the chemical business; chemical companies are entering the oil business; and the whole group is expanding greatly, so most organic chemical substances could be considered petrochemicals. More than 3000 individual petrochemicals are now in commerce, and it is beyond the scope of this report to deal with the use of all these chemicals.

cent of carbon dioxide (OECD, 1989). The shares of emissions in the different sectors of the economy vary widely from one country to another and depend on the amount and composition of fuel used and on the emission abatement technologies in place.

Table 11 Pollutants emitted from combustion of residual oil and natural gas in stationary sources for heat production

Pollutant (t)	Residual Oil	Natural Gas
Sulphur oxides	2000	1.2
Nitrogen oxides	1350	1188.0
Carbon monoxide	38	33.0
Hydrocarbons	26	1.9
Other organics	13	13.0
Particulate matter	65	28.0

- Values are normalized for the production of 1 TWh(t), i.e. 3.6 X10^{15} Joule
-The amount of residual oil used is 102,000 tonne
-The amount of natural gas used is 12,200 cubic metre.
- Source: El-Hinnawi (1981); UNEP (1985).

Table 12 Pollutants emitted from combustion of residual oil and natural gas for electricity production

Pollutant (t)	Residual oil	Natural Gas
Sulphur oxides	4200	2.3
Nitrogen oxides	2850	2300.0
Carbon monoxide	81	69.7
Hydrocarbons	54	4.0
Other organics	27	27.0
Particulates	137	58.0

-Values are normalized for the generation of 1 TWh(e)
-The amount of residual oil used is 215,000 tonne
-The amount of natural gas used is 25,600 cubic metres
-Source : El-Hinnawi (1981); UNEP (1985)

The transport sector plays a prominent role in generating virtually all the major air pollutants, especially in cities. Petrol-burning vehicles emit carbon dioxide, carbon monoxide, hydrocarbons, oxides of nitrogen, particulate and trace compounds. In confined places and congested streets, carbon monoxide concentrations can rise to levels hazardous to health, especially to people with heart or lung weakness. Oxides of nitrogen and hydrocarbons interact in the presence of sunlight to produce an oxidant smog which irritates the eyes and lungs, and damages sensitive plants. In countries where leaded petrol is used,almost alllead in air emissions in cities is from vehicle exhausts.

Although diesel-powered vehicles emit comparable or less carbon monoxide and hydrocarbons than petrol-powered cars, they emit 30-50 times more particulate matter (Springer, 1982; McClellan, 1987). Some 80-90 per cent of such particulates are less than one micrometre in diameter and, hence, are easily transported by air currents, and readily settle in the lower respiratory tract when inhaled. These particulates contain hundreds of organic compounds, several of them carcinogenic.

Because of growing concern about air pollution, programmes were initiated in several countries to monitor the common pollutants and assess changes in air quality. Monitoring data have revealed a mixed picture: although the air quality in several urban areas in the developed countries has improved as a result of different regulatory and technical measures, it has deteriorated in most urban centres in developing countries as a result of the rapid increase in the number of vehicles, lack of maintenance and inefficient application of regulatory measures. It has been estimated that more than 900 million people living in urban areas around the world are exposed to unhealthy levels of sulphur dioxide, and more than 1000 million people are exposed to excessive levels of particulates (UNEP, 1992).

Pollutants emitted into the atmosphere do not necessarily remain confined in the area near the source of emission or the local environment. They can be transported over long distances, cross frontiers, and create regional and global environmental problems. Acidic deposition is one of these problems that have been identified in North America and Europe (Rodhe et al., 1988; UNEP, 1991). There are indications that some developing regions are beginning to experience such problem, especially if current trends in urbanization and industrialization continue into the 21st century. In the ESCWA region, acid fog has been reported in some countries in the Gulf.

Carbon Dioxide and Climate Change :

The amount of carbon dioxide emitted into the atmosphere from all human activities has been estimated at 7,000 million tonnes of carbon per year. Of this amount, about 5,700 million tonnes are attributed to fossil fuel burning[4]; the remainder to deforestation and biomass burning. About 40-60 per cent of the carbon dioxide emitted into the atmosphere remains there, at least in the short term; the rest is taken up by natural sinks, particularly the ocean. Future atmospheric carbon dioxide concentrations depend on the amounts of carbon dioxide released from future fossil fuel burning (which are determined by the amount and type of energy sources to be used), the carbon dioxide released from biotic sources, and the uptake of carbon dioxide by various natural sinks. The Intergovernmental Panel on Climate Change (IPCC) has estimated that if anthropogenic emissions of carbon dioxide could be kept at present day rates, atmospheric carbon dioxide would increase to 460-560 ppm by the year 2100 (pre-industrial concentration was 280 ppm; at present it is

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[4]. Oil consumbtion concributed about 2,000 million tonnes; natural gas about 1,000 million tonnes; and coal about 2,700 million tonnes. On a unit energy basis, coal emits more carbon dioxide (26 kg C/GJ) than oil (20 kg C/GJ) or natural gas (15 kg C/GJ).

about 355 ppm) (IPCC, 1990; UNEP, 1992).

Several models have been developed to estimate possible climate change due to the increase of carbon dioxide and other greenhouse gases in the atmosphere (IPCC, 1990; UNEP, 1992). The IPCC predicted that under the "business-as-usual" scenario (without actions to reduce emissions of greenhouse gases) global warming could reach 2-5 degrees C over the next century (with the best estimate around 3 degrees C). However, detailed analyses of temperature records of the past 100 years indicate that the global mean temperature has risen by only 0.3-0.6 degrees C, which is within the range of natural climate variability (Johnes et al., 1986).

Many uncertainties prevail around the issue of global warming and its possible consequences. Recent refined models indicate that the increase in temperature would be only about 1.5 degrees C over the next century. Accordingly, many nations are against setting fixed targets for the reduction of carbon dioxide emissions from fossil fuel burning.

POLLUTION REDUCTION

Energy consumption is the product of many decisions made by countless energy users, large and small. Such decisions depend on many economic factors such as incomes, costs, investments and taxes. Energy consumption also depends on technologies and on efficiencies of energy use, on climate and geography, on social patterns and norms, on government regulations, on environmental priorities and requirements and on perceptions of the role that energy plays in human affairs. These factors interact differently, and have different implications for different nations, and among different users. Increasing the efficiency of energy use (oil products and natural gas) in stationary and mobile sources would contribute considerably to reduction of different air emissions, and indirectly to the overall environmental impacts of the wole oil and natural gas fuel cycles.

Studies over the last two decades show that in developed market economies energy intensity (defined as the amount of energy consumption per unit of the GDP of a country) declined by about 30% ; in Eastern Europe and the former USSR it declined by 20% ; but in developing countries energy intensity has risen by 30% over the same period. These average percentages must be carefully interpreted. First, these averages conceal marked differences between countries. Second, over the past two decades many actions were taken simultaneously and the changes in energy intensity are too aggregated to isolate the effects of one factor, such as energy-efficient actions taken. For example, several developed countries abandoned energy-intensive industries (or relocated them in some developing countries), and opened less energy-consuming industries. These structural changes, in addition to changes in production levels and fuel substitution, occurred at the same time as enhancements in the efficiency of production, transportation and utilization of energy. In the already industrialized countries, these factors brought together the marked decline in energy intensity.

On the other hand, in the developing countries, the increase in energy intensity reflects growing industrialization (especially the growth of energy-intensive industries), concentration on building massive infrastructures, the shift from non-commercial to commercial sources of energy (e.g. from wood and agricultural residues in rural areas to coal, kerosene or other commercial fuels), increased personal use of commercial energy, etc. But the increase of energy intensity in the developing countries reflects also true energy inefficiency. In some developing countries, industry often consumes two to five times as much fuel for a given process due to the use of old industrial equipment. Many building and transport systems are old and lack proper maintenance, and hence are energy inefficient. The situation has been aggravated by heavy subsidization of energy prices to all types of consumers, poor metering of consumption (or its total absence in some cases) and high losses in energy transmission.

In spite of this complex situation, many energy efficiency improvements have been made, especially in the developed countries. More energy-efficient lighting systems, household appliances, air-conditioners, cars, industrial equipment and many other goods have been manufactured. A multibillion dollar market in more energy-efficient technologies has been created; and this has encouraged manufacturers to invest in such technologies. These technological developments constitute one element of what is known today as "Demand-side Management", DSM. Other elements include : regulatory measures, incentives and disincentives, research and development, and the more complicated element : changing human behaviour. Recent independent studies in the USA and in Europe show that by DSM programmes, utilities saved electricity at an average cost of 2 cents/ kWh, far less than the cost of producing such power. In other words, improving the efficiency with which electricity is used costs less than building and operating new power plants.

Over the past two decades, significant progress has been made in increasing the energy efficiency of new cars. New passenger cars are now almost twice as efficient as those of the early 1970s (Renner, 1988; OECD, 1990; Graedel et al., 1995). This higher efficiency has been achieved mainly by weight reduction of cars, through substitution of steel by aluminium, plastic and ceramics in car manufacture, and by improvements in engines and transmission.

Most energy-efficiency improvements can produce direct environmental benefits in two ways :
First, benefits can be related to the reduction in energy input requirements per unit of output, which in turn generally reduces the quantity of pollutants generated per unit of useful work. But it should be noted that the absolute environmental benefits derived in this manner from greater energy efficiency will vary with the type of energy being saved (as pollutants vary by energy source), the extent of the efficiency gained and the nature of the energy process. Most importantly, the improvement in pollution levels will vary according to the pollutant considered: some pollutants are fuel dependent (such as carbon dioxide and sulphur oxides); other pollutants (such as nitrogen oxides, carbon monoxide and volatile organic compounds) are technology dependent.
Second, improvements in energy efficiency usually generate secondary environmental

benefits through the effect that reduced energy use has on the environmental impact of the whole fuel cycle.

Increasing the efficiency of energy use is the only practical ways of curbing the increase in carbon dioxide emissions, and hence, addressing the question of possible global warming and climate change. This fact has been declared by the Second World Climate Conference convened in 1990, and stressed in AGENDA-21, adopted by the UN Conference on Environment and Development convened in Rio de Janeiro in 1992. Some studies indicate that a worldwide improvement of energy efficiency by 2 % annually would keep carbon dioxide concentration in the atmosphere at about 460 ppm in 2075, and this will not cause any marked change in the world's climate (El-Hinnawi, 1995).

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