OIL

A LIFE CYCLE ANALYSIS OF ITS HEALTH AND ENVIRONMENTAL IMPACTS

Lee Stoetzel, Oil, 2000, Oil on paper mounted to aluminum, 20 x 30 inches Courtesy of the artist and Mixed Greens (www.mixedgreens.com)

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Definitions

VOCs: Volatile Organic Compounds
NOxs - Oxides of Nitrogen
SOxs - Oxides of Sulfur
H_2S - Hydrogen Sulfide
CO - Carbon Monoxide
CO_2 – Carbon Dioxide
1 micron = 1 millionth (10^{-6}) of a meter
PM-10s - Particulate matter with a diameter of 10 microns or less
PM-2.5s - Particulate matter with a diameter of 2.5 microns or less
Pb – Lead
PAHs - Polycyclic Aromatic Hydrocarbons

An oiled penguin walks the beach after a South African oil spill

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Introduction

When significant deposits of oil were discovered in the 19th Century, this fossil fuel appeared to offer a limitless source of energy to drive development. While oil and the energy it supplies provide multiple benefits to human society, every stage in the life cycle from exploration to use can have harmful effects on our health and the environment. This report examines the health and environmental impacts of oil exploration, drilling, extraction, transport, refining and combustion.

Drilling and extraction carry acute and chronic hazards, including fires and blowouts, occupational injury and disease, and can lead to long-term harm to plant and animal communities. Oil spills and leaks along coastlines pose risks for marine life and fisheries, and can threaten the livelihoods of human communities. Refining exposes workers and wildlife to petroleum, its by-products and the chemicals used in the refining process. At the pump, gasoline can be both toxic and carcinogenic.

Refining and combustion result in air pollution and acid rain. Pollutant chemicals can be toxic to humans, other animals and plants, while acid rain has impacts on terrestrial, aquatic and marine coastal systems. Finally, the aggregate of gas and particulate emissions from burning oil have begun to alter the world's climate system; with implications for human health, agricultural productivity, vulnerable ecosystems and societal infrastructure.

This report, while not exhaustive, is intended to provide a comprehensive framework for evaluating the true costs of our use of oil.The authors hope it will serve as a resource for further study.

View of an oil rig from a helicopt

Key Points

Oil Extraction

• Each year, 0.75-1.8 billion gallons of crude oil are unintentionally released into the environment.

• Occupationally-related fatalities among workers in the oil and gas extraction process are higher than deaths for workers from all other U.S.industries combined.

• Oil well workers risk injury and chronic disease from exposure to chemicals such as cadmium, arsenic, cyanide, PAHs and lead.

• Gulf Coast offshore oil rigs contaminate sediments, fish and fish consumers with mercury at levels far exceeding EPA standards.

• Spills,explosions,fires and blowouts have multiple environmental and public health impacts.

• Operational discharges of water, drill cuttings and mud have chronic effects on benthic (bottom-dwelling) marine communities,mammals,birds and humans.

• Inadequately regulated drilling of oil has harmed sensitive ecosystems in several developing countries.

Oil Transport

• Spills and leaks from the transport of petroleum and petroleum by-products occur from the point of extraction to refineries and to the sites of consumption.

• According to the Oil Spill Intelligence Report, 1999, approximately 32 million gallons of oil spilled worldwide into marine and inland environments as a result of 257 transport incidents that year.

• While large tanker accidents attract the most attention, the cumulative effect of spills and chronic leaks cause the greatest environmental damage and harm to wildlife communities.

• Many leaks and spills occur in developing nations where safety regulations for pipelines and oil rigs are inadequately enforced.

• Coastal marine and human communities in developed nations also experience significant impacts from oil spills and leaks.

• Marine mammals are affected by the oiling of their fur and skin, and through consumption of oil-contaminated foods (e.g., mussels),or via inhalation of fumes that have liver, kidney and central nervous system toxicity.

• The marine mammals most commonly affected include: seals, sea otters,walruses, sea lions and whales; manatees and dugongs (in tropical waters); and polar bears in the Arctic. (Detailed in appendix of report.)

• Sea otters are particularly vulnerable as they feed near the surface, have little blubber and depend upon an intact fur coat to maintain their body temperature.

Oil Refining

• Oil, by-products and chemicals used in the refining process cause chemical, thermal,and noise pollution.

• Oil refining affects the health and safety of refinery workers through accidents and from chronic illness (e.g.,leukemia) associated with exposure to petroleum and its by-products (e.g.,benzene).

• Petroleum refineries present major health hazards for human communities living near refineries, and for marine and terrestrial ecosystems where they are situated.

• Regulations on labor, safety, emission standards and environmental protection are often inadequate in developing nations and in poor communities in developed nations.

Gasoline

• Gasoline and many of its additives can lead to acute and chronic toxicity, and is associated with some types of cancer.

• Groups at high risk for exposure to gasoline and its additives include: employees in the distribution, storage and pumping of gasoline;people living near refineries, transfer and storage facilities,and service stations;automobile drivers who pump their own gas; people who live in houses with attached garages; and those whose drinking water has been contaminated with gasoline.

• Despite the well-recognized health impacts of lead poisoning, and evidence that reduction in the lead content of gasoline significantly diminishes lead-related morbidity, much of the gasoline available in the developing world remains leaded.

Combustion: Air Pollution

• Gas flaring at the point of extraction is a source of air pollution.

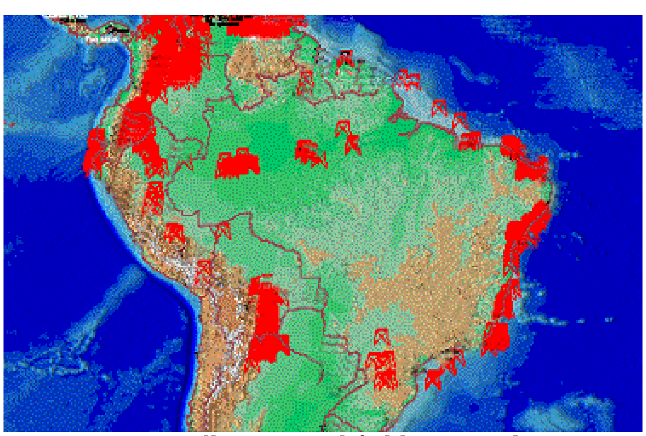
• The additives and products of oil combustion, VOCs, NOxs, SOxs, CO, CO2, PM-10s, PM-2.5s and Pb (definitions on p. 2), have numerous environmental and human health impacts.

• Chemical and particulate air pollution are related to heart and lung disease (chronic obstructive lung disease and asthma) and premature death.

• NOxs and VOCs combine to form ground level ozone (O3) or photochemical smog.

• This reaction is temperature-dependent; thus warming increases the formation of photochemical smog and may reverse gains made in attaining ground level ozone standards.

• Subsequent to the 1970 Clean Air Act, the U.S. has made substantial efforts towards controlling air pollution. However, studies demonstrate that even allowable levels of many of the pollutants result in significant negative health effects.



A GIS map illustrating oil fields in South America

Combustion:Acid Rain

• Acids formed from oxides of nitrogen (NOxs) and sulfur (SOxs) acidify all forms of precipitation.

• The anticipated recovery of acidified soils appears to be a longer, more protracted process than originally projected, as the depletion of minerals (calcium and magnesium) persists even after correction of soil acidity.

• Calcium and magnesium deficiencies in soils harm plants and animals.

• Acidification leaches lead,copper and aluminum into drinking water.

• NOxs from oil combustion (along with sewage and fertilizer runoff) cause eutrophication of lakes, estuaries and marine coasts.

• Eutrophication (excessive nitrogen and phosphorus) contributes to harmful algal blooms in inland waters and coastal "red tides" that contaminate seafood, and leads to biologically unproductive "dead zones".

Combustion: Climate Change

• Over the past 150 years, human activities -- including the combustion of fossil fuels and land clearing -- have altered the levels of atmospheric greenhouse gases; the most important being carbon dioxide.

• CO_2 levels are now greater than they have been for 420,000 years and they are rising.

• Land surfaces and the deep ocean are warming, altering Earth's ice cover, accelerating the hydrological (water) cycle and changing global weather patterns.

• Droughts are becoming more severe and persistent,adding to the depletion of fresh water supplies in water-stressed areas, and increasing the vulnerability of agricultural resources.

• Melting of permafrost threatens the integrity of northern latitude pipelines.

• Warming and the accompanying extreme weather events threaten health, forests and marine coastal ecosystems.

Conclusion

Oil has many benefits and energy is necessary for all our activities. But each stage in its life cycle carries hazards for humans, wildlife and the environmental systems on which we and other species depend. Dependence on oil has also skewed incomes within nations and altered power relations among them. Efficiency gains, and more diffuse and distributed generation, could transform the current system into one that is healthier, less costly and more resilient.

The transition to clean and efficient energy technologies will depend on nationally and internationally coordinated policies and incentives. Understanding the health and environmental consequences of oil use may help decision makers assess the true costs of our dependence on this non-renewable resource.

Figure 1: Effects of Oil Recovery by Stage

STAGE	EFFECT	SUBCATEGORY
Exploration	Deforestation	Emerging infectious diseases
Drilling and Extraction	Chronic Environmental Degradation	• Discharges of hydrocarbons, water and mud; increased concentrations of naturally occurring radioactive materials
	Physical Fouling	• Reduction of fisheries • Reduced air quality resulting from flaring and evaporation • Soils contamination • Morbidity and mortality of seabirds, marine mammals and sea turtles
	Habitat Disruption	• Noise effects on animals • Pipeline channeling through estuaries • Artificial islands
	Occupational Hazards	• Injury, dermatitis, lung disease, mental health impacts, cancer
	Livestock Destruction	
Transport	Spills	•Destruction of farmland, terrestrial and coastal marine communities • Contamination of groundwater • Death of vegetation • Disruption of food chain
Refining	Environmental Damage	• Hydrocarbons • Thermal pollution • Noise pollution, ecosystem disruption
	Hazardous Material	•Chronic lung disease
	Exposure	• Mental Disturbance • Neoplasms
	Accidents	• Direct damages from fires, explosions,chemical leaks and spills
Combustion	Air Pollution	• Particulates • Ground level ozone
	Acid Rain	• NOx, SOx • Acidification of soil •Eutrophication; aquatic and coastal marine
	Climate Change	• Global warming and extreme weather events, with associated impacts on agriculture, infrastructure, and human health

Figure 2: Global Distribution of Proven Oil Reserves at the End of 2000 (Statistical Review of World Energy, 2001)

Region	Barrels in billions	Percentage of Total
Africa	74.8	7.1
Asia Pacific	44.0	4.2
Europe	19.1	1.8
Former Soviet Union	65.3	6.2
Middle East	683.6	65.3
North America	64.4	6.2
South & Central America	95.2	9.1
TOTAL	1046.4	100
OECD†	84.8	8.1
OPEC††	814.4	77.8

†OECD Members:Australia,Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States.

††OPEC Members:Algeria, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates, Venezuela.

Figure 3: Number of Global Oil Drilling Sites

Region	Land	Off-Shore	Total
EUROPE	39	50	89
MIDDLE EAST	141	28	169
AFRICA	32	28	60
LATIN AMERICA	218	52	270
ASIA PACIFIC	93	61	154
CANADA	339	5	444
UNTIED STATES	776	140	916
MEXICO	38	6	44
TOTAL	1776	360	2146

I. EXPLORATION, DRILLING AND EXTRACTION

There are hundreds of oil-waste pits in the Oriente [Ecuador], perhaps more than a thousand. Many of them are situated right on the streams that provide drinking, fishing, and bathing water for local communities. A typical pit is about the size of an Olympic swimming pool and is nothing more than a hole dug out of the forest floor. Raw crude oil, toxic drilling wastes, formation water (water that is pumped up from the ground along with petroleum and carries such heavy metals as arsenic, cadmium, cyanide, lead, and mercury), maintenance wastes (including industrial solvents and acids), and the related effluvia of the oil-extraction process are regularly dumped into such pits and the pits regularly wash out in the Oriente's heavy rains.

Joe Kane, Savages (1996)

A. Scope

There are approximately 40,000 oil fields in the world, but less than five percent of them contained 95 percent of the total world oil reserves when first discovered. Moreover, crude oil reserves are dominated by 38 "super-giant" fields, originally containing more than five billion barrels and holding over 50 percent of the world's reserves (Gilbert, 1993). Industrial nations tend to be large consumers of oil and oil products, but minor producers. Among the OECD (Organization for Economic Cooperation and Development) nations, only Mexico, Norway and Britain are oil self-sufficient, whereas the rest of the industrialized world is highly dependent upon the Organization of Petroleum Exporting Countries (OPEC), and particularly the Middle Eastern nations, for oil supplies. Sixty-six percent of the current reserves are located in the Middle East, but ME countries produce only 26 percent of today's global supply (Gilbert, 1993). The largest non-Middle Eastern oil exporting countries include Venezuela, Nigeria, Indonesia, Libya,Algeria, Ecuador, and Gabon. As oil has yielded higher prices, extraction has moved offshore, and platform drilling off the continental shelves has steadily grown to meet an increasing global demand.

The environmental and public health hazards associated with exploration, drilling and extraction in the life cycle of oil are broad in scope and in the degree of impact. The general environmental effects of encroachment into natural habitats and the chronic effects of drilling and generating mud and discharge water on benthic (bottom-dwelling) populations, migratory bird populations and marine mammals constitute serious environmental concerns for these ecosystems. Drilling of oil poses health risks to workers, including acute (traumatic) and chronic illness from long-term exposure, respiratory and dermatological diseases, and malignancies.

On-shore projects can have serious negative effects on water sources, fisheries and livestock, potentially harming fishing and farming communities. Acute events such as spills, explosions, fires and blowouts occur with relative frequency during drilling operations. These events can cause loss of life and do extensive damage to local environments.

This section of the report presents a brief discussion of the technical aspects of exploration, drilling, and extraction. It then addresses the physical disruption, chemical pollution and biological harm to surrounding communities, including the human health consequences from fires, blowouts and spills. Finally, case studies will be presented illustrating general points made throughout this section.

B. The Technical Process

Exploration

As the search for the "ever-elusive hydrocarbon" has become increasingly difficult, the industry has moved beyond random drilling to more sophisticated detection techniques (Surdam, R.C., 1997). Airplanes and satellites make remote sensing possible, using a combination of photography, radar, infrared imagery, microwave frequency receivers and other technologies to identify possible production areas and to predict the likelihood of significant reserves (Beaumont and Foster, 1992; Legg, 1994). The primary benefits resulting from these advances are threefold: first, they allow for a preliminary assessment of environmental impact potential prior to setting foot on the ground (Legg, 1994); a related second, they may reduce the environmental despoliation resulting from exploration; and third, these advances can cut the overall costs of exploration. However, the statistical improvement is so far only 28% over random drilling, raising overall efficiency to around 60% (Surdam, 1997). This means that land-based testing, while conducted less broadly, is still required and that such testing, despite the environmental effects, has a continuing failure rate of about 40%. Environmental impact assessments, universally recognized as crucial steps in environmental protection, are often not conducted or go unheeded.

During land-based exploration, drilling is conducted to determine the nature and extent of potential oil and gas reserves. In regions with known reserves like California and Alaska, a surveying and siting technique called the "checkerboard method" can help limit the number of test holes required (Stanley – USGS, 1995). But in developing countries where reserves are less-explored, test drilling is more extensive. These operations are usually brief, involve a small number of wells, and are generally conducted from mobile platforms or vessels. The first stage of exploration -- 3-D seismic surveys -- requires a caravan of survey equipment. While new techniques attempt to reduce the associated disruption, this process involves vibrating and recording vehicles, personnel carriers, mechanic trucks, mobile shop trucks, fuel tankers, an incinerator, a crew of 80 to 120 people, shipping containers, tractors and other equipment. Mobile rigs employed for temporary drilling can weigh over two million pounds and discharge large amounts of mud and cuttings.

Once oil and gas is found, development begins with the drilling of 10 to 30 wells per platform. Since more wells are drilled during development than during exploration, a larger volume of drilling mud and cuttings is discharged in this process. Once the drilling unit used in development is removed, extraction of hydrocarbons from the underground formation begins (Menzie, 1983).

Drilling and Extraction

Offshore oil platforms produce a wide variety of liquid, solid and gaseous wastes, some discharged directly into the ocean. Onshore oil production operations produce quantities of cuttings and mud, ranging from 60,000 to 300,000 gallons per day, while offshore oil platforms use nearly 400,000 gallons of water per day, released directly into the ocean. Lined pits for disposal are sometimes used in association with land rigs, but mud, drill cuttings, and other materials are often discharged into the ground.

More troublesome still, some extraction techniques require the use of sub-surface explosives, or 'torpedoing' to breach certain geologic features. However, even this can fail to produce the desired effect. One engineering text goes so far as to suggest the following: "In cases where the use of chemical explosives is not effective, nuclear charges may be employed" (Schumacher, 1980). If such a suggestion were only hypothetical,it might be easily dismissed. But apparently such operations were carried out, mostly in the former Soviet Union, with enough 'success' that the text goes on to contend, "peaceful nuclear explosions will help to unseal and put into operation enormous deposits" (Schumacher, 1980).

C. Environmental Impacts

Exploring for oil carries particular risks for plant habitat, wildlife and human communities. Exploration usually involves moving heavy equipment into relatively pristine environmental areas, disrupting -- sometimes deforesting -- the habitat and allowing human encroachment. Air and ground transport vehicles require landing strips and new roads, further contributing to the fragmentation of habitats. The exploration crew can introduce infectious disease to previously unexposed (immunologically-naïve) populations, or can contract new diseases from penetration into the exploration site. Deforestation itself can lead to the emergence of new infectious diseases. Cultural clashes with local populations occasionally occur.

Great quantities of water -- often a limited resource -- are used during exploration, particularly in inland sites. In areas with permafrost, millions of gallons of water are used to create ice access roads in winter across the tundra. Overdrawn surface water sources can harm invertebrates and fish that feed migrating fowl, while depletion of underground aquifers can have long-term implications for entire ecosystems, farming activities and human communities.

Water used and contaminated during extraction, or 'produced water' as it is known in the industry, generally contains varying quantities of heavy metals, volatile aromatic hydrocarbons (such as benzene, toluene and xylene) and a vast array of other potentially toxic compounds. Produced water can be treated using a range of mitigation techniques including filtration, biological processes, and reverse osmosis before being reintroduced into the environment (Reed and Johnsen, 1995). But these methods entail a great deal of expense and seem to be employed selectively. Likewise, since certain geologic features commonly associated with the exploitation of oil are also associated with underground water systems, many extraction operations have the requisite preconditions for widespread contamination (Legg, 1994). Avoiding contamination of adjacent water supplies often requires a costly combination of fracture and hydro-geologic analyses; costs unlikely to be incurred except where environmental standards require these activities.

Physical Disruption

Although physical alteration from oil exploration is difficult to quantify, fishermen and environmentalists alike consider it to have a greater environmental impact than do large oil spills. The effect of drilling structures, discharge cuttings, artificial islands and pipelines all impact coastal habitats. Canalization of land surfaces for pipeline routing and navigation in coastal wetlands are extremely disruptive to ecosystems, often allowing saltwater intrusion into brackish ecosystems. Noise and physical disturbances affect bird, mammal and turtle populations, while artificial islands and causeways in the Arctic alter the living conditions of benthic communities and fish (Boesch and Rabalais, 1987).

In developing countries, pipelines are often laid above ground because it is less expensive than burying the pipes. These obtrusive, leaking structures can disrupt livestock, farmland, and the habitat of human and animal communities. Sometimes oilrigs become artificial reefs and provide underwater habitat for marine life.

Chemical Pollutants

Petroleum itself, oil-based drilling fluids and the byproducts of drilling, including water, drill cuttings and mud have been studied extensively. The chemical composition of each of these substances varies according to the drilling methods employed and the specific commercial product generated. The toxins, irritants and general pollutants include alkalis, bactericides, soluble chromates, mercury and corrosion inhibitors. Because methods for disposal of mud at the end of a job vary, depending on governing authorities and mud composition (AIME, 1975), the precise impact of these chemicals on dynamic ecosystems is difficult to quantify. Unfortunately, the unknown and complex chronic effects may be the most serious ones for the environment. However, a general understanding of how chemical pollution from drilling effects the environment provides avenues for investigation into specific categories of impact.These include:

1. **Chronic effects** from the persistence of medium and high molecular weight aromatic hydrocarbons, including heterocyclics and their degradation products, in sediments and cold environments.

2. **Residual damage** from oil spills to complex biological communities, such as coastal wetlands, reefs and vegetation beds.

3. **Effects on benthic organisms** from discharges accumulated through field development and exploratory drilling.

4. **Effects of water discharges** into near shore rather than open shelf environments.

Recent studies suggest that aromatic hydrocarbons, including heterocyclic chemicals can mimic hormones, causing deleterious developmental and reproductive effects in wildlife and humans

(Colborn et al., 1996). Female petrochemical workers exposed to organic solvents are at increased risk of having prolonged menstrual cycles (oligomenorrhea).Those with three or more years of exposure had a 53% higher risk (Cho et al., 2001). Although the ecological significance of "endocrine disrupters" has not been resolved, offshore drilling discharges -- containing polyaromatic hydrocarbons and alkyl phenols (Lye, 2000) -- may be one source of such contamination.

NORM Pollution

Naturally occurring radioactive materials (NORMs) are commonly found in underground geologic deposits and are frequently brought to the surface during crude oil recovery. Normally quite stable and insoluble, some radium leaching to the environment is possible as a result of acid-rain exposure and the aging processes. "Non-negligible" exposure to humans living and working in contaminated areas is most likely to occur via waterborne pathways. (Rajaretnam and Spitz, 2000). NORM wastes result from a diverse range of industrial activities, but are not as carefully monitored in the oil industry as in other forms of mining. It has been suggested that if NORM-contaminated by-products were to be disposed of properly, existing low-level radioactive waste facilities would be 'readily occupied' (Paschoa, 1998). New studies reveal that even low-level radiation may have mutagenic impacts (Zhou et al., 2001).

Biological Effects

Media images of dead and dying oil-covered marine wildlife have sparked considerable public concern over the effect of offshore oil development. Massive kill events do occur, but the long-term impacts of leaks and chronic discharges may be of greater significance for animal populations (especially endangered) and migratory sites for birds and marine mammals. Over the past 15 years, studies indicate oil fouling as a cause of mortality in seals, sea otters, several species of whales,and sea turtles (Boesch and Rabalais, 1987). Bioaccumulation of oil and other products in mammals and fish that are consumed by humans is a further concern. Livelihoods can be at risk; the reduction of fishery stocks due to mortality of eggs and larvae as a result of oil leaks and spills creates economic burdens on fishing communities.

Onshore drilling poses risks for livestock. Crude oil and salt water spills, common occurrences around production sites, and pipeline breaks can all expose livestock to crude oil or refined petroleum hydrocarbons. Ingestion of petroleum hydrocarbons by livestock can cause sudden death (Edwards, 1989). Solvents and petroleum hydrocarbon components can cause aspiration pneumonia and rumen dysfunction, while certain petroleum additives can cause methemogolobinemia (Edwards and Gregory, 1991).

High doses of drilling effluent cause various clinical signs in livestock, including tremors, nystagmus, vomiting and pulmonary distress (Khan et al., 1996). Exposures occur when the petroleum or chemicals used in oil and gas field activities are available to cattle, or when water and feedstuffs are contaminated (Coppock et al., 1995).

CASE REPORTS - COWS

- Eleven of 80 Holstein cows were found dead in a pasture. A barrel of unknown chemicals had rusted and leaked near an oil well. Animals were observed to have spasmodic seizures at the time of death.
- Thirteen of 28 cows were found dead near a gas well. The rumen pH at necropsy was 9.6. The postmortem blood was chocolate brown. A green liquid was leaking from a tank near the oil well.
- Fifteen of 300 head of cattle were found dead in a pasture where an oil well was being drilled. Cattle had been observed licking a white granular material from broken 50-pound sacks.
- Four of 10 heifers were found dead near an oil well. There was a strong smell of solvent in the rumen contents.
- Two of 40 Hereford cows consumed liquid coming from a pit near an oil well. Necropsy revealed profuse watery and bloody diarrhea.
- Ten cows and three calves in a herd of 21 Limosine cows were found dead in a pasture where oil drilling was in progress. The cows had consumed liquid leaking from the well site. Six cows were found dead near a drilling site. The cows had consumed a yellow brown powder (Edwards and Gregory, 1991).

D. Human Health Impacts

Mercury contamination and offshore drilling

Mercury contamination of fish has become an increasing route of human exposure to this neurotoxin, believed to cause birth defects, and heart problems – and more severe neurological disorders ("Minamata disease") and death with very high levels. Coal-fired plants have long been known to contribute mercury to the environment. In a study of oil rigs in the Gulf of Mexico mercury levels were up to 12 times higher than the safe level, by EPA standards, in muds and sediments beneath the platforms (Raines, 2002). Fish caught in the Gulf -- groupers, amberjack, yellowfin tuna, reds snapper, swordfish and others -- were found to have mercury levels that made them unsafe for sale, according to the *Mobile Register*. Humans eating gulf coast fish once a week have high levels of mercury in their samples.

WARRI, NIGERIA

In October of 1998, a pipeline in the Nigerian Delta town of Warri burst and caught fire, resulting in over 700 deaths; 500 immediately and an additional 200 within the next week (Anon., 1998). Facing severe fuel shortages, hundreds of local residents had gathered around the burst pipeline in order to collect the oil that flowed from the breakage, "It was like a marketplace," said Chief John Ogude of Warri (Walsh, 1998). Around the leak, "The vast pool of fuel covering an area the size of a football field was then accidentally ignited" (Holman, 1998) and exploded into flames reaching as high as 20 meters (Walsh, 1998).

Explosions

In July 1988, an explosion and subsequent fire in the North Sea Piper Alpha platform, owned by Occidental Co., killed 160 (Onuba, 1991). Unfortunately, such accidents are not uncommon.

DRILLING IN NIGERIA

Although the quantity of oil drilling in Nigeria is small compared to that done in many other nations, lack of regulatory bodies and dependence on oil for income have led to sub-standard production operations. Oil pollution from normal operations -- that include spills, accidents, leaks and waste discharges -- have caused significant ecological damage to the Niger River Delta. Shell Oil alone reported 130 spills in 1997; attributing 53 to equipment failure, 23 to human error and 54 to sabotage by those frustrated with the government and oil industry (Susman, 1998). Conditions in one Delta community were described as follows:

In the nearby Obagi community, open flares of natural gas, a by-product of crude oil, are burned off daily, emitting a pungent smell that tingles the nostrils… New galvanized rooftops are caked with rust within two years, thanks to acid rain. And miles of brown, rusting oil pipelines that dot the landscape often leak or burst, sending streams of sticky black liquid into the fields (Simmons, 1998).

According to the Moffat/Linden report(1995), at least 2300 cubic meters of oil -- from at least 300 spills -- contaminate the Niger Delta region annually. This is the "official" number reported.The actual amount of oil spilled annually "may be 10 times higher" (Moffat and Linden, 1995). The devastating fire in Warri in 1998 that killed at least 700 residents in the vicinity of a burst pipeline is probably the most dramatic and illustrative of the risks that oil exploration poses for public health. The accumulated effects of hundreds of oil spills and leaks, however, as well as the atmospheric contamination through continuous gas flaring, pose long-term and widespread health hazards for local communities.

Early oil rigs:

"…the so-called standard rig would have horrified today's safety professionals…Flying ropes and kicked-back boards caused untold numbers of broken arms and ribs, smashed faces, and cracked skulls. Despite their drawbacks, cable tool rigs were used all over the world from the Baku oilfields of Russia to New Zealand as the oil demand grew." (Berger and Anderson, 1992). Cable tool rigs are still used on land today, but improvements have made them safer and more mobile than their predecessors.

Offshore drilling workers still face multiple hazards and report high levels of stress and anxiety (Mueller et al., 1987). Long shifts and stressful schedules, combined with wet, slippery conditions, rough seas and heavy machinery moving at high velocities, create dangerous work conditions.

Oil and gas exploration and drilling are the most hazardous sectors of the oil industry (Guidotti, 1995). **Occupationally-related fatalities among workers in the oil and gas extraction process are higher than deaths for workers from all other U.S. industries combined.** In 1991, non-fatal work-related injuries for workers in the U.S. oil and gas field service industry were 49% greater than injuries for workers in all of private industry. Injuries also tend to be more severe, with lost workday rates more than 2.8 fold higher than those in private industry (McNabb et al., 1994).

[Data compiled by the International Association of Drilling Contractors, an industry wide international trade association representing 95% of the world's oil and gas drilling companies.]

In addition to death and injury, workmen in the oil and gas industry also suffer from a variety of dermatological conditions, most commonly contact dermatitis and acne. Other conditions include kerototic facial and neck lesions, neoplastic change of the skin from exposure to oil and sunlight, and acquired perforating disease and calcinosis of the hands and fingers (Knox et al., 1986;Wheeland and Roundtree, 1985). Tests have shown a correlation between anti-estrogenic activity, mutagenicity and exposure levels to the polycyclic aromatic com pounds associated with crude and slurry oils (Arcaro, 2001).

"Hard metal" -- a mixture of tungsten carbide and cobalt -- is widely used for industrial purposes, including oil well drilling bits. Adverse pulmonary reactions to hard metals include asthma, hypersensitivity pneumonitis and interstitial pulmonary fibrosis (Cugell, 1992). The last two illnesses are often fatal.

Drilling generally requires the use of fluids to lubricate and cool these 'hard metal' drill bits. Standard practice into the 1980s was to use diesel-based fluids, but their volatility posed obvious risks. Modern substitutes include low-aromatic oil-based fluids. But these may pose new risks in that testing of related substances has shown them to be more efficiently distributed to the brain. Likewise, little is known about the carcinogenic potential of long-term exposure (Eide, 1990).

Working conditions in developing countries are, overall, more hazardous than those in developed countries. Basic health requirements for staff are not carried out in many parts of the world (Onuba, 1991), and poor regulatory systems often increase the risks of occupational injury and death.

In spite of these North/South inequities, the U.S. is not immune to sub-standard working conditions. A single case of severe diarrhea on a floating Texas oilrig preceded by two days the largest cholera epidemic in the U.S. in over a century. The outbreak was associated with an open valve that permitted contamination of the rig's drinking water by canal water containing sewage discharged from the rig (Johnston et al., 1983).

Although several oil companies are involved in production activities in the Niger Delta region, including Mobil, Chevron, and Texaco (Susman, 1998), Royal Dutch/Shell Petroleum Corporation is the leading oil producer in Nigeria. Having dug its first well in 1956, Royal Dutch/Shell now controls the over half of Nigeria's oil production. Both local and international communities have primarily targeted Shell for the poor environmental standards and the harsh conditions that exist in the Delta. The production of oil in the Niger Delta, which has been criticized by Shell's former Nigerian head of environmental studies as "not meeting international standards," (Kuper, 1996) has been reported to be the single largest world contributor to global climate change through releases of carbon dioxide and methane associated with production activities (Penman, 1995). Withdrawing temporarily in 1993, Shell has since reentered the Delta despite increasing protests, both peaceful and violent, against its involvement in the region. Shell has been implicated in hiring mercenary armies to provide protection against local populations whose violent protests jeopardize the stability of oil extraction activities. Oil has failed to alleviate the suffering of Nigeria's people and has devastated the Delta environment.

E. Spills, Explosions, Fires and Blowouts

Serious accidents can occur during the drilling and extraction processes. Blowouts of wells (caused by pressure build up in front of the drill head), platform collapses or collisions with ships, pipeline ruptures, leaks and accidents in transferring oil and gas between facilities, and fires and explosions all constitute major public health hazards. Notable well blowouts that caused large-scale oil spills occurred in 1969 in Santa Barbara, California, in 1977 in Ekofisk in the North Sea, and in 1979 in Ixtoc, Gulf of Mexico.

A 1981 report by the National Academy of Sciences estimated that 36 million gallons of oil are released into the oceans each year as a result of all offshore oil and gas operations(MAS, 1981). This amounts to about 2% of the total annual input from all spills (Menzie, 1983). When oil spills occur in the open sea, there may be immediate effects upon planktonic organisms and seabirds along the surface. In shallow, low-energy embayments, tidal flats and estuaries, the impacts of oil spills can be more severe. There can be immediate effects on near-shore marine bird populations, benthic vertebrates and fish. Mortality rates among birds coated with oil is particularly high as a result of loss of buoyancy and dehydration. Spilled oil may also be incorporated into the sediment, with chronic effects on benthic populations and pelagic (open ocean) fish.

Offshore wells drilled in icy waters present unique problems. In the shallow Beaufort Sea drilling must be performed from artificial islands and these islands and associated pipelines are vulnerable to drifting ice. In deeper water to the north, drilling is carried out from mobile ice islands and drilling becomes impossible if an ice platform moves a distance more than 5% of the total depth of water from the drill-hole. If a blowout occurs,a gas hole may seal itself. But,an oil well blowout usually requires a counter-well to stop the flow; a process that can take up to a year, considering northern latitude working conditions. During this delay, oil accumulates under the drifting ice and is carried to other parts of the Arctic Ocean (Bourne, 1978).

Fires

Fires present one of the most severe acute threats to human life in the oil industry. Oil is extremely flammable, and the products of combustion are dangerous in high concentrations. The burning oil wells produces large amounts of gases such as SO_2, CO, CO_2, H_2S, and NOxs, as well as particulate matter made up of partially burned hydrocarbons and metals:All of these are potentially hazardous to human health and to vegetation (Husain, 1995).

In the context of war, oil fields and oil transportation systems are at high risk of sabotage, and large oil fires, induced oil spills, and oil well blowouts occur. The Persian Gulf War is a prime example of deliberate sabotage of oil operations. Approximately 22,000 tons of sulfur dioxide, 18,000 tons of soot, and thousands of tons of carbon monoxide and oxides of nitrogen were emitted daily by the burning wells in Kuwait (Husain, 1995). In addition, tons of toxic metals and carcinogenic compounds were released into the atmosphere (Kelsey et al., 1994).

THE 1991 GULF WAR

According to the Petroleum Economist (1992), just before the conclusion of the Gulf war, the Iraqi military successfully detonated 730 wells with explosive material, causing fiery blowouts. Six hundred and fifty-six of the exploded wells burned for several months and the remaining 74 gushed oil, forming lakes that covered an area of 16 square miles (Husain, 1995), creating an "environmental catastrophe … unparalleled in the history of mankind" (Husain, 1995). Estimates are that approximately 1.5 billion barrels (63 billion gallons) of crude oil (1.5-2% of the oil reserve in Kuwait) were lost to fires during this period. This corresponds to millions of tons of pollutants emitted into the atmosphere, and 1.05-1.7 billion gallons of oil deposited on the surface of Kuwait. In addition to the loss of resources, estimated to be over $U.S. 30 billion, the population in the region was exposed to contaminated air for several months (Husain, 1995). The blowouts deposited a coating of oil mist on the leaves of plants, depriving them of sunlight, and the fallout from the plumes on the Arabian Gulf seriously threatened the marine ecosystem. Furthermore, sabotage by the Iraqis spilled an estimated 460 million gallons of crude oil into the Arabian Gulf in the third week of January 1991, causing what is considered to be the largest oil spill in history.

DRILLING IN ECUADOR

The pollution is worse every day. Everyone has a cough or other sickness.
-- Gabriel Alatorre, Petroecuador mechanic in Shushufindi, Ecuador (Althaus, 1996)

The Ecuadorean Amazon, known as the Oriente, was once one of the richest ecological and sparsely populated sites in the world. When oil was discovered there in 1967, the situation changed dramatically. Extremely high levels of water pollution of drinking, bathing, and fishing waters in the Oriente have been attributed to contamination from unlined waste pits (Brooke, 1994). More than 600 of these toxic waste pits were created during Texaco's involvement in Ecuador between 1972 and 1990 (Kane, 1996). Texaco used such pits set into the ground to store toxic byproducts from oil production and separation.The lack of barriers allowed waste to leak into the surrounding soil. Ecuador's Undersecretary for the Environment, Jorge Alban, reports that Texaco, while having cleaned 268 waste pits, has not cleaned at least 400 pits and these are not included in the cleanup plan signed by Texaco, Petroecuador and the Ecuadorean government (Schemo, 1998).

Oil pollution in local water supplies vastly exceeds international standards. According to the EPA, the level of polycyclic aromatic hydrocarbons (PAHs) deemed acceptable in water is zero, as they are strong carcinogens. The EPA standard in the U.S. is for a maximum PAH concentration of 28 nanograms per liter of water, corresponding to a one in 100,000 lifetime risk of cancer. Samples of drinking water collected near oil production facilities in the Oriente ranged from 33 to 2,793 nanograms of PAHs per liter of water -- counts up to one hundred times the EPA's safety guidelines. Bathing and fishing waters had concentrations ranging from 40 to 1,486 nanograms per liter, and water from waste pits ranged from 46,500 to 405,634 nanograms per liter (Brooke, 1994).

Ecuador's debt has created a dependency upon oil that has pressured the government into two compromising policies: to accept substandard operational practices by oil companies and to open ecologically-sensitive areas to exploration and production, disregarding the effects on indigenous populations. Neither action involved consideration of indigenous groups that have lived in the Oriente for centuries, and rarely were indigenous groups informed of oil production or settlement plans. The Ecuadorean government has estimated the cost of environmental damage to be $5 billion and has asked Texaco for reparations for cleanup costs in the region (Parrish and Long, 1994).

DRILLING IN MEXICO

For the past two decades the state of Tabasco in Mexico has experienced ecological and social crises stemming from the exploitation of the states' oil reserves by Petroleos Mexicanos, the national oil company. Although this exploitation has generated U.S. $130 billion over 20 years, the state is the ninth poorest in Mexico. Unregulated oil extraction has escalated living costs, skewed income distribution, forced relocations and led to hazardous living conditions. The release of toxic substances and disruption of water supplies have damaged crops and depleted fish populations (Chelala, 1998). Studies performed in the area by Jose Luis Cortes Penaloza indicate that cancer and leukemia are increasing in all age groups in Tabasco, with the highest leukemia incidences reported in areas immediately surrounding petroleum production sites (Chelala, 1998).

The environmental consequences of the Kuwaiti oil fires were unprecedented, resulting in massive death to fish, bird and marine organisms. There were profound changes to air and water quality, and the sheer quantity of carbon emissions contributed to global climate change. Unfortunately, the human health impacts of this event have not been rigorously assessed, but there is anecdotal evidence that children experienced respiratory and dermatological diseases and growth retardation; as well as an undefined wasting syndrome not previously experienced in the relatively affluent population. It is possible that these clinical manifestations resulted from the oil fires and spills (Doucet, 1994). Exposure to large volumes of burning oil is also associated with aplastic anemia (Stern et al., 1994).

F. Human Rights and Environmental Legal Implications

Traditional international law forbids foreign intervention in matters that are "essentially within the domestic jurisdiction of any state" (United Nations Charter, Article 2.7), and it recognizes the authority of a state to exercise exclusive, permanent sovereignty over the natural resources present within its boundaries (Hunter et al., 1998). Thus, states have historically enjoyed nearly absolute discretion regarding what happens inside their territory.

However, recent decades have seen a limited erosion of absolute state sovereignty, particularly in the area of human rights, but also in environmental law. Human rights, generally, are meant to guarantee certain minimum protection to all people everywhere. These rights include many of the so-called civil rights, such as the rights of due process, freedom of expression and political affiliation, and,most fundamentally, the right to life. All of these civil rights have often been abused when frustrated individuals have spoken out against the environmental damage resulting from oil exploitation. In response to such abuses, human rights advocacy groups, like Amnesty International and Human Rights Watch, have joined forces with environmental non-governmental organizations such as the Sierra Club and the National Resources Defense Council in efforts to defend those "who give the earth a voice" (Sierra/Amnesty Report, 2000. See also, HRW/NRDC, 1992).

But beyond efforts to protect the human rights of environmental activists, a number of prominent human rights and environmental lawyers and scholars contend that there is an emerging human right to a healthy environment.As evidence, they point to more than 60 national constitutions that either endow citizens with a right to an environment of a certain quality or impose obligations on the government to protect the environment (Kiss and Shelton, 2000). Ecuador's Constitution, for example, promises a "right to live in an environment free of contamination," (Constitución Política de la República de Ecuador, 1979, article 19.2).

Unfortunately, the problem in Ecuador is indicative of a more global problem: lack of enforcement. The exploitation of oil reserves, like other natural resources, has a tendency to exact the greatest environmental toll where governments lack the will or the resources to enforce legal standards. The worst instances most often involve oppressive regimes and multinational corporations, each impervious to the pressures of international law. Several civil suits have been filed against U.S. corporations for alleged damage done by their subsidiaries abroad, but with limited success for the plaintiffs. A combination of legal action, improving human rights mechanisms, and public relations concerns may eventually bring about a change in course. Meanwhile, the exploration, drilling and extraction of oil continues to pose substantial threats to the health of vulnerable people and their environs (CESR, 1994).

F. Chapter summary

There are significant occupational hazards of land-based and coastal marine offshore exploration, drilling and extraction of oil. Drilling is one of the most hazardous professions in terms of mortality, injury, mental health and chronic diseases that include pneumoconiosis, cancers and dermatological disorders. Environmental effects include acute and chronic degradation of terrestrial and near coastal habitats. Unpredicted pressure pockets, equipment failure, and sabotage are causes of explosions, fires and formation of oil lakes.

The chronic effects of drilling operations are more difficult to quantify. Process leaks, during standard operating conditions, waste disposal and spills can generate continuous releases of hydrocarbons and other effluents. The variety of materials used throughout the industry and the different environments and depths in which drilling operations are conducted continue to make analysis of compounding influences difficult.

II. POPULATION MOVEMENTS AND INFECTIOUS DISEASES

Drilling and exploration have direct effects on health due to population movements. Oil attracts workers and their families to sparsely inhabited areas, sometime causing rapid "urbanization," introduction of infectious diseases and mental health disorders. The exploration crew can also be a source of new epidemics and cultural clashes with local populations.

Malaria, the world's most prevalent vector-borne disease, has been historically linked to population movements. The movement of infected people from areas where malaria is endemic to areas where the disease had been eradicated has contributed to the resurgence of disease (McMichael et al., 1996). Population movements can also affect the risk of acquiring malaria because of the effect on both the environment and vectors. Deforestation and irrigation systems create favorable habitats for the mosquitoes, while population movements can transport the disease and spread drug resistant strains (Wolfe et al., 2000).

Oil drilling has also been linked in rural areas with population mixing between infected people and individuals in areas of high susceptibility. Oil workers often work for a week and then return to their families for a week. During these shifts, workers come into contact with one another under crowded conditions, creating a high potential for disease transmission. Workers can then bring the diseases back to their respective communities.

Population movements and transitions from rural, non-industrialized and traditional societies to urban, industrialized, "modern" society can also have impacts on mental health. In New Mexico, studies found rapid industrialization to correlate with an increase in broken families, divorces, neglected children, alcoholism and lawlessness.

DRILLING IN THE PERUVIAN AMAZON

The Urarina are a semi-nomadic Amazonian indigenous group who, for 500 years have inhabited the Chambira and Urituyacu river basins north of the Marañon River in Peru, located 450 km from the department capital of Iquitos. They resisted outside contact with missionaries and colonists for years, accounting for their unique language and their survival as a distinct people. The Urarina are one of the largest isolated Amazonian indigenous groups in Peru that remain without government recognition; they have neither citizen's rights nor control over their lands.

The Urarina land includes a flood zone believed to have significant oil reserves. The Peruvian oil company has owned this field, and in 1996 and 1997, the drilling rights were transferred to a British oil company. The company was able to enter and exploit the Urarina land by using the "divide and rule" scheme, securing the signature of one individual who did not necessarily represent the views and wishes of the entire community. The Urarina were not properly represented and received no form of compensation. This type of fraudulent contract is difficult to nullify.

In addition to the ecological devastation associated with oil spills and chemical wastes in this region, the Urarina people have been affected by diseases imported by oil workers. The oil company drilling subcontractor uses the port community of Santa Clara to load equipment onto barges for transport to Chambira and, in 1996-1997, Santa Clara suffered the most intense, drug resistant *Plasmodium falciparum* epidemic of any area of Peru. Resistant *P. falciparum* strains first appeared in the Urarina population in Chambira in November 1997, apparently imported by the oil workers. Over 60% of the malaria strains were resistant to chloroquine and fansidar.

Pertussis (whooping cough) also first appeared on the Chambira in February 1997,along with the arrival of oil drilling teams. Seven persons from two villages died. Mortality data from the rest of the Urarina are lacking, but rates are likely to be high due to the lack of vaccination coverage.

There is additional concern that sexual contact between foreign male workers and local women may lead to the introduction and spread of sexually transmitted diseases, including HIV/AIDS.

- **Other Implications**

Fossil fuel-related dislocations can be associated with other risks. In Burma, for example, the threat of infectious disease is secondary to the more acute dangers of serious human rights violations. The Unocal Oil Company of California and Europe's Elf-Total-Fina group have been implicated as conspiring with and funding the Burmese military (Kanchanaburi, 1999; European Information Service, 2001).The military, in turn, has forced subsistence, minority farmers from their lands and then conscripted them to work on the construction of the country's Yadana pipeline, benefiting the companies and the Government while harming biodiversity and disrupting local communities (Sierra/Amnesty Report, 2000). Citizens who dare to speak out in protest are dealt with ruthlessly, and "would-be saboteurs" face oil-funded artillery and rapid response battalions (Sierra/Amnesty Report, 2000; Kanchanaburi, 1999). Unocal has been sued in U.S. courts, and Elf-Total-Fina blasted by members of the European Parliament for their alleged involvement in these atrocities; but their operations continue (Tulacz, 1996; European Information Service, 2001). A federal court in Los Angeles warned Unocal that liability would stem from proof that the company had conspired "to deny the civil rights of the Burmese plaintiffs to further its financial interests." But this standard has been difficult to meet, and the people of Burma are still very much at risk (Mabro, 1997).

III. TRANSPORT

A. Introduction

Crude oil is found in nature, and at any point in time there are millions of gallons of crude oil naturally seeping into the environment. This seepage accounts for 10%, approximately 20-340 million gallons, of the estimated quantity of crude oil spilled into the oceans each year (Burger, 1997). This seepage has created a delicate balance between the organisms that inhabit the environs near oil seepages and the potential damage that oil can inflict upon the environment.

Environmental degradation from the use of oil has affected the earth ever since the ancient Egyptians set flame to oil-filled trenches during warfare. But before the 1960s when oil transportation technology began to flourish, the degradation was relatively small in scale. With the massive shift to oil and gas came an explosion of environmental insults caused by large-scale oil spills and accidents, most frequently occurring during transport.

This section focuses on the impact of the transport of oil and oil derivatives across the globe. The role of oil in the modern world has created the need for increasingly complex transportation methodologies that allow oil to be carried to all regions of the earth. Unfortunately, gaps between effectiveness and safety, combined with the potential for human error, have resulted in significant ecological disasters.

B. Oil Spills

Since most of the earth's oil is found under the oceans, robust technology has emerged to transport extracted oil from the seas to refineries and, from there, to the myriad distribution points around the globe. Immense networks of pipelines crisscross the globe carrying oil and natural gas, underwater and above and below ground, from extraction points to refineries. There are more miles of oil pipeline than railroad tracks in the world (Burger, 1997) and enormous super-tankers, laden with oil, circumnavigate the earth's seas. From coasts, tank barges trudge along rivers transporting oil to inland destinations. Then, tank trucks, replete with oil, cruise the world's highways racing to distribution and storage points all over the globe. Accidents have occurred at each point of transfer and transport, exposing the environment to the various harmful effects of oil contamination. As technology has progressed, the scale of these disasters has increased, though their frequency has declined due to regulations and increased safety measures.

Large-scale oil spills, defined as spills of over 10 million gallons, have occurred almost every year since the 1960s. Except for the Kuwaiti oil spill, most large-scale oil spills are the result of grounded supertankers or supertanker collisions.

Over the past four decades, supertankers have dramatically increased their carrying capacity. In 1960, a supertanker could carry 150 million gallons of oil; today they can carry over 240 million gallons. Tankers are over 300 meters long and are some of the least maneuverable vessels at sea, making them extremely prone to accidents. In the United States, the Exxon Valdez spill in Prince William Sound, Alaska increased general awareness concerning the danger of oil spills and forced the U.S. government to take new regulatory action. That spill leaked over 11 million gallons of oil into the pristine Sound, blackening the frigid waters and coating the coastline with oil (Burger, 1997). Although it was one of the most well publicized oil spills in recent history, the Exxon Valdez spill ranks only 28th in terms of scale. Following is a table of the largest oil spills in history.

Figure 4: The Largest Oil Spills in History

Name and Place	Year	Cause	Millions of Gallons
1. Terminals, Tankers, Pipelines, Persian Gulf	1991	Gulf War	240.0
2. Ixtoc-1 oil well, off Mexico	1979	Blowout	140
3. Nowruz Field, Arabia	1980	Operations	80
4. Fergana Valley, Uzbekistan	1992	Operations	80
5. *Castillo de Bellver*, off South Africa	1983	Fire	78.5
6. *Amoco Cadiz*, off NW France	1978	Grounding	68.7
7. *Atlantic Express* and *Aegean Captain*, off Trinidad and Tobago	1979	Collision	48.8
8. Well, 480 mi SE of Tripoli, Libya	1980	Operations	42
9. *Irenes Serenade*, Greece	1980	Grounding	36.6
10. *Torrey Canyon*, of SW UK	1967	Grounding	35
11. *Sea Star*, off Oman	1972	Collision	34
12. Storage Tanks, Shuaybah, Kuwait	1981	Operations	31.2
13. *Urquiola*, off N. Spain	1976	Grounding	29.0
14. *Hawaiian Patriot*, N. Pacific	1977	Fire	29.0
15. *Braer*, Shetland Islands	1993	Grounding	25.0
16. *Sea Empress*, Wales	1996	Grounding	24.0
17. Pipeline, Usinsk, Russia	1994	Burst Pipe	23.0

Adapted from Cutter Information Corp., 1995, International Oil Spill Statistics: 1994, Cutter Information Corp., Arlington, MA.

Such large-scale oil spills occur against a backdrop of more frequent smaller-scale spills that receive little attention. Smaller spills have also contributed significantly to environmental degradation. **The quantity of oil released from the combination of smaller accidents, operational leaks and pipeline bursts actually greatly surpasses the amount released from the large spills from super-tankers.** In much of the world, it is these smaller scale pipeline accidents and leaks, in conjunction with the leaks and discharges from the extraction and refining processes, that contribute most heavily to environmental damage.

At every point along this chain there are leaks and spills of crude oil or petroleum products. The transfer of oil from the wells to storage tankers, from storage tankers to supertanker, from supertankers to storage tankers or tank barges, from storage tankers to truck tankers, etc. can all entail oil spillage. In addition to leaks and spills, pipeline fires and blowouts occur. Pipelines carry oil and gas all over the world, and are able to function 24 hours a day, under any weather conditions. Because of this non-stop capability, pipelines are preferable to supertankers. Unfortunately, there are large initial costs in building safe pipelines and relatively large recurrent costs in maintaining them. Many companies neglect pipeline maintenance, which contributes to pipeline accidents throughout the world.

Pipelines are high-pressured conduits for the transfer of large volumes of oil,varying in width and carrying capacity. They are very prone to corrosion at points that connect the various pipeline components. Pipelines burst relatively frequently due to faulty equipment, causing spills and raising the potential for oil or gas fires. **The life span of a pipeline is acknowledged to be 15 years.** Unfortunately, many of the pipelines in current use are older and therefore prone to leakage and rupture, posing serious threats to neighboring populations and surrounding environments.

C. Environmental Impacts of Oil Spills

Physical Characteristics of Oil in the Environment

Oil is less dense than water, causing it to float on the surface of water after a spill. Typically, one ton of oil covers approximately $12km^2$ of water. Beyond that a slick begins to fragment. The size of a spill, the type of oil spilled and the timing of the spill all affect how much ecological damage the spill will incur. The impacts also depend upon the type of ecosystem in which the spill takes place and its vulnerability or resilience to the insult.

A large spill can do extensive damage to large areas of ocean (or land), smothering the small microorganisms that comprise the bottom of the food chain. In smaller spills, neighboring organisms often recolonize relatively quickly. But after a very large spill, recolonization and replenishment of microorganisms from surrounding areas can be greatly delayed. It is important to note that because of the effects of oil spills on vegetation, water and fish, the impacts of even small spills can send ripples into surrounding ecosystems and affect communities beyond the immediate spill area.

The type of oil that comprises a spill also determines the effect it will have upon a given ecosystem. All oil contains both heavy and light chain hydrocarbons. Oil with a high proportion of light chain hydrocarbons will have less of an impact upon an ecosystem, because the molecules are volatile and evaporate more easily than those with heavy chains. Oil comprised of more heavy chain hydrocarbons spreads and will cling to plants, rocks, sand and boulders.

After oil enters the environment it undergoes a process called "weathering" or degradation. Weathering consists of the following stages:

• **Spreading**- Spilled oil immediately begins to spread over the sea surface initially as a single slick covering extensive areas. The slick later begins to break up forming narrow bands parallel to the direction of the wind. The rate of oil spread depends on the viscosity of the oil and the prevailing conditions, including sea surface temperature, water currents, tidal streams and wind speeds.

• **Evaporation**- Lighter components of the oil evaporate into the atmosphere, with the amount and speed of evaporation depending upon the oil's volatility. The most toxic components, toluene and benzene, are also the most soluble and flammable, and these evaporate in the first 24-48 hours.

• **Natural dispersion**- Waves and turbulence at the sea surface causes all or part of a slick to break up into fragments and droplets of varying sizes. The speed of dispersion depends on the nature of the oil and varies with the weight and volatility of the oil and local conditions. The addition of chemical dispersants accelerates the process of natural dispersion.

• **Emulsification**- Emulsification refers to the process in which seawater droplets become suspended in the oil. The emulsion formed can be very viscous and is more persistent than the original oil spilled. It is referred to as "chocolate mousse" because of its appearance. The emulsion expands the volume of the pollutants three to four fold. If the concentration of asphaltene in the oil is greater than 0.5%, the emulsion will be very stable and can persist for months.

• **Dissolution**- Water-soluble compounds in oil may dissolve into the surrounding water, especially if the oil is finely dispersed in the water. When light aromatic hydrocarbon compounds like benzene and toluene are the primary components, these are lost through evaporation and dissolution is limited.

• **Oxidation-** Oils react slowly with atmospheric oxygen, creating soluble degradation products or forming compounds called tars (with an outer protective coating of heavy compounds that increase the oil's persistence). This process is promoted by sunlight.

• **Sedimentation/Sinking-**333Heavy, refined products with densities greater than 1, will sink in fresh or brackish water. Sinking usually occurs due to the addition of sediment particles or organic matter.

• **Biodegradation-**Biodegradation is process by which microorganisms in seawater partially or completely degrade oil into water-soluble compounds and eventually to carbon dioxide and water. Microbes that biodegrade oils are specific to the compounds and some compounds -- like degraded tars and asphaltene -- are highly resistant to attack. The process takes place at the oil-water interface. The creation of oil droplets by natural or chemical dispersion increases the surface area of the oil, and therefore the area accessible to biodegradation. The efficiency of the process depends on the levels of nutrients (nitrogen and phosphorus) in the water, sea surface temperature and the level of oxygen present.

Ecosystem Effects

Acutely, the main victims of oil spills are the animals and plants that inhabit coastal and oceanic environments. The acute toxicity of oil is such that many animals die as a result of oil ingestion. The viscosity of oil also poses a threat to mammals and avians; oil coats the fur of sea otters and the feathers of birds, preventing these outer layers from insulating against hypothermia. The hydrocarbons that comprise oil are also carcinogenic to fish, birds and mammals, and there is evidence that oil is immunotoxic to sea birds (Briggs et al., 1996). Seals and sea lions suffer cancerous lesions from ingestion of oil, and may drown because of the extra weight of oil on their coats. Evidence also suggests that oil spills and exposure to chronic low levels of oil in the sea decrease the reproductive rate of seals (Jenssen, 1996).

Oil spills can cause widespread mortality in fish populations, with cascading impacts for other species – especially birds, marine mammals and human populations — that depend highly upon fish for subsistence.

<u>Fiddler crabs - key indicators</u>

The coastal subtidal zone (underwater at all times) and intertidal zone (covered only during high tide) are inhabited by multiple small invertebrates. The fiddler crab, a species that inhabits the intertidal zone, is regarded as the "canary in a coal mine" for oil spills. This invertebrate is present in the estuarine habitats around the world and is therefore a universal indicator for the impact of oil spills on coastal ecosystems. As with other organisms, fiddler crabs exhibit dose-response mortality due to oil toxicity. Thus the status of the fiddler crab population in an area after an oil spill is a sensitive marker for the severity of the spill.

Oil spills can affect plant life in subtle but sometimes profound ways. Each coastal ecosystem has different susceptibilities to contamination. In temperate regions, salt marshes are most vulnerable. Salt marsh plants are relatively short, measuring up to three feet in height. Because they are low, salt marshes can be completely covered by the oil after a spill. In tropical regions mangrove swamps are susceptible to damage from oil spills as their roots are above ground. An unimpeded interface between roots and air is required in order for the plant to "breathe" and exchange salt. Thus oil spills have killed extensive swaths of mangroves. Mangrove swamps are an ecological lynchpin. They protect the shoreline integrity and are the nurseries for many shellfish and finfish, providing nutrition and protection from predation. The death of a large portion of a mangrove system can threaten the organisms dependent upon them for survival.

Humans can be affected by oil spills from damage to surrounding plants and animals, and perhaps by direct contamination. Most information on direct effects is anecdotal (Campbell et al., 1993). One Scottish study found an increase in the reporting of nausea, headache, throat irritation and itchy eyes in local populations following spills. But long-term effects are unknown. Rigorous clinical studies are needed to assess the direct effects of oil spills on human beings.

Oil Spills on Land

Oil spills that occur on land, primarily from pipeline leaks and accidents, can contaminate surrounding soils and groundwater. A large oil spill can make contaminated land uncultivable -- placing subsistence farmers at risk for food insecurity -- and eliminate the safe drinking water supply for a community.

Case study: REVISITING NIGERIA

Nigeria is one of the poorest nations in the world, with a per capita annual income of $320. This is despite the natural oil reserves resulting in over $30 billion annual in revenue for the government and much more for The Royal Dutch Shell Company, a company that controls over 50% of the oil wealth in Nigeria. While the average Nigerian derives little benefit from the natural oil wealth of Nigeria, he (she) does suffer from the environmental consequences of poorly controlled oil exploration.

Most of the oil in Nigeria is found within the Niger River Delta, the largest delta in Africa and the third largest in the world (HRW, 1999). The inhabitants of the Niger Delta are primarily ethnic minorities, who are socially, politically and economically marginalized.

The Nigerian government owns 60% of Shell's oil industry in Nigeria and has an incentive to produce and transport oil as cheaply as possible. On paper, oil companies operating in Nigeria are supposed to adhere to "good oil field practices," implying that they will abide by the Institute of Petroleum Safety Codes, the American Petroleum Institute Codes or the American Society of Mechanical Engineers Codes.These codes, however, are not enforced, and oil companies act with relative impunity in the Niger Delta, establishing a double standard between operating procedures in Africa and in the developed world. These factors and a history of disregard for human rights have led to large-scale human and environmental damage.

More specifically, Shell has issued its Royal Dutch/Shell Group Statement of General Business Principles in which the company promises to "conduct its activities to take account of health and safety and to give proper regard to the conservation of the environment" (Kiss and Shelton, 2000). This and similar codes of conduct are entered into voluntarily by industries, generally in their attempts to avoid criticism and the imposition of binding regulations. However, the voluntary nature of these codes allows for broad discrepancies in implementation. For example, while one company may perceive a long-term strategic advantage by investing in and implementing more socially and environmentally responsible practices, another company may use its code as a public relations tool and little else. Enforcement, as it were, sometimes occurs when consumers refuse to purchase the products of a company that fails to uphold its promises, or through litigation for negligence or malpractice. However, consumer sanctions require widespread awareness and sympathy among the purchasing public, and legal actions can be prolonged for years.

One expectation of oil companies is that they are supposed to be responsible for the investigation and clean up of oil spills in a timely fashion. The oil industry in Nigeria has often not fulfilled this responsibility. Affected communities often have little power and the Nigerian government has been unable to enforce clean-up efforts. As one ex-oil executive stated, "The oil industry claims that approximately 2,300 cubic meters of oil are spilled annually in the Niger Delta. Reliable sources conservatively place the actual number at ten times the industry's claim. The Nigerian Department of Petroleum Resources believes 45 million U.S. gallons of oil have been spilled into the Delta, but this too is a gross underestimate" (HRW, 1999). According to a recent report the CIA has disclosed that "years of oil spills in the Niger Delta, which have yet to be cleaned up, amount to the equivalent of 10 times the Alaskan Exxon Valdez oil spill" (Wysham, 2001).

The inhabitants of the Niger Delta are farmers and fishermen. They live off of the land and are dependent upon the productivity of that land for survival. Destruction of farmland by oil contamination has pushed tens of thousands of people to the brink of starvation and prevented income generation from that land. Ogoniland, the traditional land of the Ogoni people and situated on top of some of Nigeria's largest oil reserves, has experienced been severely impacted. After the discovery of oil, above ground pipelines were constructed through farms, roads were built on land owned by locals and people were relocated against their will. All this has threatened the Ogoni way of life.

Whereas most pipelines are buried underground, the majority of pipelines in the Niger Delta are situated above ground, rendering them susceptible to physical damage and corrosion. The Niger Delta has many small oil fields interconnected by pipelines and by networks of flow lines -- small diameter pipes that carry oil from wellheads to flow stations. The high pressure in these small pipes makes them especially susceptible to leaks. Pipelines tend to leak at a rate of four spills per week.These leaks and spills contaminate groundwater and destroy the soil, significantly decreasing crop yields. Fisheries, farms, mangrove swamps, rainforests and water have all suffered severe damage from oil, threatening the survival of the people of the Niger Delta.

Gas flaring

Oil production contributes to air pollution in the form of flaring, the burning of natural gas extracted along with crude oil. Flaring is the cheapest way to dispose of the natural gas that Nigeria is not equipped to utilize. Worldwide, this process contributes 35 million tons of carbon dioxide annually as well as 12 million tons of methane, two very potent greenhouse gases. The flaring also fills the air with smoke and covers the land in soot, meanwhile contributing to the rising acidity of the rain (Moffat and Linden, 1995). Seventy six percent of the natural gas that is a by-product of oil extraction has been flared in Nigeria, covering the surrounding area with black soot.

[For Saudi Arabia, the figure is 20%; Iran 19%; Mexico 5%, Britain 4.3%; Algeria 4%; Former Soviet Union 1.5%; U.S. 0.6%; Netherlands 0%.]

The search for oil in the Niger Delta also causes deforestation. Local populations deforest swamps in search of arable land uncontaminated by oil (Simmons, 1998) and clearing of mangrove swamps may prove to be one of the most long-lasting side effects of oil spills. Without mangroves, riverbanks will erode, leading to flooding that could further harm the Niger Delta.

Punctuating the chronic small oil spills, there have been significant large-scale oil spills that place surrounding communities in immediate danger of starvation. As recently as 1998, individual oil spills have devastated several communities and undermined their means of subsistence. In 1998, 840,000 U.S. gallons spilled at Shell's Jones Creek flow station. This spill was a result of what Shell called "a pipeline failure." Shell officials claimed that relief materials, such as food, water and seeds were distributed to the affected communities; but this was not corroborated (HRW, 1999).

There have been no comprehensive studies examining the direct health effects of oil upon human populations, and oil companies have funded all the studies that have been performed. Bopp van Dessel, the former head of the environmental studies division at Shell stated, "It was clear to me that Shell was devastating the [the Niger Delta] area."

Populations most affected by oil exploration have protested the abuse and disregard of their land, but the Nigerian government and Royal Dutch Shell have suppressed opposition movements. The most prominent display of this suppression was the public hanging of the highly respected activist Ken Saro-Wiwa in 1998 for mobilizing tens of thousands of people under the banner of the Movement for the Survival of the Ogoni People (MSOP). The mission of MSOP was to protest both the policies of the federal government regarding oil, and the practices of Royal Dutch Shell. The government charged Saro-Wiwa formally with the murder of four traditional leaders. But it is widely accepted that this charge was a false pretext.

Nigeria presents a tragic example of all that can go wrong in the oil industry. From the point of extraction, through the transportation process, to the export phase, the oil industry in Nigeria has done very little to advance overall development and protect human rights. With the execution of Ken Saro-Wiwa, the oil industry came under intense scrutiny, and it has been forced to change its practices and provide some compensation to the people whose lives and land it has devastated. The progress is slow, however, and significant improvements remain to be realized.

Worldwide, the problems with oil transportation have not yet been properly addressed. In the U.S.. regulations establish safety parameters for supertankers and maintenance, and usage parameters for pipelines, truck tankers and other forms of transportation. However, many governments throughout the world fail to make these kinds of safety commitments; and even when such parameters do exist, they are frequently ignored and are difficult to enforce.

Furthermore, global climate change may, itself, undermine the integrity of some energy sources. Global warming, accelerated by the practices of oil industry, is slowly thawing the permafrost in which the Alaskan pipeline is embedded. The permafrost provides the pipeline with the stability it requires to prevent chronic leaks and potentially disastrous accidents.

IV. REFINING

Once extracted, crude oil is transported to an oil refinery where complex hydrocarbon compounds are separated, converted, and treated, becoming useable fuel sources. Separation, of which fractional distillation is the most commonly employed technique, involves the division of the crude mixtures by either boiling or vaporizing the crude oil in fractionating towers. The temperature within these towers is controlled to allow different substances within the crude oil vapors to condense and collect at different temperatures. Solvent extraction is another separation method, but instead of using heat, solvents are employed to separate the petroleum into various layers that are later extracted. The next stage, conversion, alters the less valuable fractions achieved through separation into more valuable products, such as gasoline. This is accomplished most commonly through *cracking*. Thermal cracking uses heat and catalytic cracking uses catalysts to split off molecules from heavier compounds in an effort to form simpler, lighter compounds. Other forms of conversion, such as alkylation, polymerization, or hydrogenation add molecules to form other useful products. Finally, impurities are removed through chemical treatment of each product. The process of refining oil manufactures nearly 2,500 useful products (Gennaro et al., 2000), producing in 1997 approximately 3.5 billion tons of oil refined products (IEA, 1997). The major end product of oil is gasoline, followed by diesel fuel, jet fuel, fuel oils, kerosene, lubricating oils, and asphalt used for road paving.

A. Environmental Pollution

According to one study, 99.7% by weight of crude oil processed at one U.S. oil refinery was converted to useful products, while 0.3% of the crude oil by-products were released into the environment (Kizior, 1991). Because the average-size refinery processes over 3.8 million gallons of crude oil each day, this 0.3% results in over 11,000 gallons of oil released daily into the water, land, or air. These figures do not take into account accidental oil spills or the expulsion of other chemicals produced as by-products. As dramatic as these figures sound, many oil refineries go to great lengths to treat or filter petroleum waste, in attempts to prevent environmental damage. Water used in the refining process must be treated to remove traces of heavy metals, noxious chemicals, solvents and residual aromatic hydrocarbons before this water can be released into disposal wells or waterways. However, process units still vent dangerous hydrocarbons, flue gases such as sulfur dioxide or carbon monoxide, and particulate solids into the atmosphere. These gases can be recaptured with complex scrubbers or filters in the refinery to avoid atmospheric contamination, but complete elimination of these emissions is impossible given existing technology. Together with evaporated wastes released into the water, these gaseous emissions from the refinery accumulate in the atmosphere and return in the form of acid rain. Spent catalysts from refinery processing units are also significant contaminants and must also be properly disposed.

Oil refineries also contribute other forms of pollution. Thermal pollution involves the discharge of effluents that are significantly warmer than surrounding water, creating a localized warming effect that greatly disrupts surrounding marine ecosystems. Noise levels in refineries can exceed 90 decibels, posing a significant threat to the health and safety of oil refinery employees (Runion, 1988). Sound dampening devices built into both the machinery and the buildings themselves will reduce noise levels, but workers must still be trained in using appropriate noise protection equipment and participate in annual hearing examinations. The surrounding community benefits from these sound dampening devices because leakage of noise pollution can have significant psychological effects on local residents,decreases the aesthetics of the area, and can interfere with wildlife.

B. Chronic Occupational Hazards

There are over 700 oil refineries worldwide (API, 1987), and in 1994, about 1,219,000 workers were employed in oil refineries (ILO, 1998). Oil refinery workers are continuously exposed to numerous hazardous materials and working conditions that place them at continuous risk of injury or death. Chronic hazards include exposure to heat, polluted air, noise and hazardous materials, including asphalt, asbestos, aromatic hydrocarbons, arsenic, hexavalent chromium, nickel, carbon monoxide, coke dust, hydrogen sulfide, lead alkyls, natural gases, petroleum, phenol, and silica (Engler, 1975; Gennaro et al., 1994). Asphalt, for example, can cause severe burns and eye irritation, and its fumes may contain unacceptable levels of benzene and hydrogen sulfide, which may lead to dermatitis, bronchitis and chemically-induced pneumonia. Continuous exposure to carbon monoxide can lead to headaches and mental disturbances, and at high concentrations, death from asphyxiation. Long-term exposure to coke dust, silica and hydrogen sulfide can lead to chronic lung disease. Lead alkyls used as gasoline additives can lead to psychosis and peripheral neuropathies. Even though lead is no longer used in many developed nations, its widespread use in much of Latin America puts workers in refineries exporting to these nations at particular risk.

Asbestos, often used in oil refineries for the thermal insulation of boilers and pipes, has long been associated with pulmonary fibrosis, lung cancer and malignant mesothelioma among maintenance, repair and removal workers. Statistically significant increases in risk above baseline levels have been found among almost all epidemiological studies that have set out to analyze the mortality associated with mesotheliomas among oil refinery workers. Mortality ratios range between two and 24.4 (Gennaro et al., 2000). Even though the use of asbestos is banned in nine countries, it is still widely used in many parts of the world. The use of asbestos in developing countries is a major problem as these nations are likely to lack legislation regarding the use of asbestos, and the long-term health and safety of workers is often a low priority (Gennaro et al., 2000).

Exposure to other potentially carcinogenic materials (see NIEHS, 2000), such as benzene, toluene, xylene, arsenic and hexavalent chromium has also been widely studied and associated with an increase in cancer risk among oil refinery workers (Hayes et al., 1996). In a 1998 study, cancer incidence between 1971 and 1994 was evaluated in a cohort of 7,512 men and 1,942 women employed for at least three months at a Finnish oil refinery (Pukkala, 1998). The author concluded that the significant two to threefold relative risk of kidney cancer among oil refinery workers employed for over five years was likely attributable to occupational exposure to potentially carcinogenic compounds in oil refineries. Another study evaluated the cause-specific mortality of 2,985 male workers employed in three Texas oil refineries between 1940 and 1993 using a proportionate mortality study design (Dement et al., 1998). Proportionate mortality ratios were significantly increased ($p < .05$) for cancers of the lip, stomach, liver, pancreas, connective tissue, prostate, eye, brain, leukemia and unspecified neoplasms for the entire cohort. Refining has been studied in the North Sea industry as a probable cause for the increased rates of leukemia among children (HEI, 1995). The study found a significant increase of childhood leukemia in those rural areas of Scotland that were most affected by "mixing" associated with the North Sea oil industry.

Numerous studies have found positive associations with various forms of cancers (Clapp and Coogan, 1999). Some cohorts have excess risk for non-Hodgkin's lymphoma, and brain, stomach, bone, lung, prostate, pancreatic and kidney cancer (IARC, 1989). The International Agency for Research on Cancer (IARC) has denoted occupational exposures in the oil refining industry as "probably carcinogenic to humans" (Group II-A), a strong category that includes PCBs and herbicides. The great majority of studies that have shown no increases in mortality from cancer have been conducted among workers in developed countries. Although this is important for workers whose companies are bound by stringent rules and regulations, workers in developing countries are not afforded the same protection.

Petroleum refinery workers are not the only individuals at risk of cancer associated with refineries. A 1994 geographical analysis of leukemia clusters in childhood compared postal codes of children with leukemia, matched to control postal codes, with distances to numerous industrial installations. The 264 clusters showed relative, non-random proximities to several map features, including oil refineries (Knox, 1994). Three years later, the study was expanded to include all 22,458 children aged 0-15 years dying from leukemia or cancer in England, Wales and Scotland between 1953 and 1980. Using a similar design, the authors found that relative excesses of leukemia and of solid cancers were found near many industrial installations, particularly oil refineries, major oil storage installations, and rail-side oil distribution terminals (Knox and Gilman, 1997).

Oil refinery waste products can also have dramatic effects on surrounding communities and environments. Aromatic hydrocarbons, such as substituted benzenes and naphthalenes, enter aquatic ecosystems through a variety of routes already discussed. These compounds are mostly polar, non-water soluble and nonionic. The earliest reports implicating neoplasms in animals from presumed aromatic hydrocarbon exposure came from the brown bullhead fish (Lucké and Schlumberger, 1941), but have since then have been found in a number of marine animals (Kuehn et al., 1995). Incidences of 10-80%, and in some cases 100% of liver neoplasms, have been associated with exposures to wastes from industrial sources (Kuehn et al., 1995; Black et al., 1982). One study sampled water, sediment, and fish from three streams that had received or were receiving effluent from oil refineries. The authors concluded that the significant levels of aromatic hydrocarbons found in each of the streams contributed to important differences in the diversity and abundance of fish among the upstream, effluent-receiving, and downstream stations. For example, histological analysis confirmed that 75% of the bullheads at the upstream stations had normal livers compared with only 40% at the discharge site. In addition, 20% from the discharge site had a parasitic cyst, which was not found in any samples from the upstream station (Kuehn et al., 1995).

C. Accident Potential

Oil refineries are inherently complex in their equipment and structural design. Combined with the multitude of chemicals used, workers are at a continuous risk for accidents involving fires, explosions, and chemical leaks and spills. Explosion and fire potentials stem mainly from natural gases such as methane, propane and butane produced at the refineries. Microscopic flaws in metal pipes, fittings, or fixtures in "hydrocrackers" that operate at pressures ranging from 500 to 3,200 pounds per square inch and temperatures ranging from 500 to 1800 °F (Engler, 1975), can also lead to dangerous explosions. Accidental oil spills and leaks harm both workers and surrounding ecosystems because of exposure to petroleum and petroleum derivatives. Although oil spills most commonly occur during transport, leaking oil-storage tanks and barrels contribute significantly to chemical and oil spills at refineries. **Oil refineries and transport efforts account for approximately 46% of the estimated 3.2 million tons of oil entering the oceans each year.** The oil and oil waste products eventually leach from ground containment facilities, or are discharged directly into water, eventually dispersing into the atmosphere, water column, bottom sediments and beaches (Whittle et al., 1982). The resulting buildup of petroleum and petroleum waste matter in an area have impacts on surrounding biota and ecosystems.

D. Environmental Protection

In the United States, the petroleum refinery industry is regulated at both national and local levels. The Environmental Protection Agency sets standards for controlling these pollutants, and closely monitors refineries for compliance. At the local level, states issue permits to refineries based on compliance with a number of factors, including disturbances to vegetation and wildlife, emissions from floating roof tanks, and the potential for environmental contamination of soils or water. Other regulatory agencies mandate that petroleum companies follow safety standards protecting the health of workers against long-term exposures to potentially carcinogenic substances.These safety measures also protect against accidents harmful to both employees and the environment. Because of these standards, oil refinery companies must constantly redesign and modernize their existing plants, or build new and more efficient ones. The enormous costs of complying with these regulations, ensuring safer refineries, has pushed many U.S. oil companies to relocate to other parts of the world, namely developing countries. Developing countries eager to attract new business, offer a cheaper workforce and less stringent environmental and safety regulations.

PART 2. CONSUMPTION AND COMBUSTION

Once oil has passed the hazardous stages of extraction, transport and refinement, the end products themselves, and the by-products of their combustion pose significant threats to human and environmental health. Gasoline and its additives have been associated with acute chronic toxicities in humans. Combustion of gasoline and other refined fossil fuel products have contributed significantly to environmental pollution. Fossil fuel consumption has created numerous harmful pollutants, impacting humans and the environment in numerous ways. Individually, each pollutant holds the potential for significant impact. Collectively, they represent a much greater threat.

V. HEALTH EFFECTS OF GASOLINE AND GASOLINE ADDITIVES

Gasoline is one of the principal end products of oil, used primarily for internal combustion engines. The composition of gasoline may vary depending upon the origin of the crude oil, differences in processing, and the incorporation of various additives to improve performance. Gasoline is composed primarily of hydrocarbons, including cycloparaffins, paraffin and aromatics (King, 1992). Common additives include: metals such as alkyl lead; oxygenates such as ethanol, methanol, methyl tertiary butyl ether (MBTE), tertiary butyl alcohol (TBA), tertiary amyl methyl ether (TAME), and ethyl tertiary butyl ether (ETBE); additional aromatic hydrocarbons such as benzene, toluene and xylene; and others including ethylene dibromide (EDB), ethylene dichloride (EDC), and methyl cyclopentadienyl manganese tricarbonyl (MMT) (Caprino and Togna, 1998).

Although a great deal of effort has gone into studying the health impacts of gasoline and its additives, many questions remain about the risks associated with various types of exposure. Research has produced variable, often conflicting results. The variability of the composition of gasoline has complicated efforts to measure its safety. Additionally, the composition of a given gasoline changes over time (King, 1992), possibly impairing the accuracy and reliability of relevant data. Methodological flaws, such as failure to control for possible confounders, have further limited the usefulness of many studies, producing a confusing array of contradictory findings (Caprino and Togna, 1998). Nonetheless, a collection of animal studies, human case studies and human epidemiological studies has yielded important information about the health effects of gasoline.

A. Routes of Exposure to Gasoline

The first step in studying the health impacts of gasoline -- measuring exposure -- has proven to be difficult. Occupational exposures -- discussed in the Refining section -- define groups of people at high risk for gasoline-related illnesses. People employed in the distribution, storage and selling (pumping) of gasoline face high levels of exposure to its potentially toxic effects (Akland, 1993; Hartle, 1993). Gasoline also poses significant risks of exposure to the general population. An estimated 110 million people in the U.S. are regularly exposed to gasoline at self service-pumps, accumulating an annual average exposure of 100 minutes (Wixtrom and Brown, 1992). Drivers are also exposed to evaporative emissions, and larger numbers of people are exposed to the hazardous byproducts of gasoline combustion.

Certain groups within the general population face higher levels of gasoline exposure because of location. These groups include people who live near service stations, refineries, transfer or storage facilities; people who live in houses with attached garages; and those whose drinking water has been contaminated with gasoline (Wixtrom and Brown, 1992; Akland, 1993). Behaviors also affect risk of contact with gasoline: gasoline sniffing is a form of substance abuse that results in a high-concentration exposure to gasoline and its constituents. Sniffing gasoline has been identified as a fairly widespread practice among certain indigenous groups in North America and Australia, more common among inner city and remote rural populations (Maruff et al., 1998).

The most common form of exposure to gasoline among the general population is through inhalation of volatile fumes or combustion byproducts (Akland, 1993). Skin contact and oral ingestion are other possible means of gasoline exposure. The type and degree of gasoline-related health impacts depend greatly upon the mode and duration of exposure.

B. Acute Toxicity

Much of the available data on acute toxicity from gasoline and gasoline additives have been derived from animal studies -- often involving very high levels of exposure. The results, therefore, have limited applicability to humans. Case studies of either intentional or accidental exposure to large doses of gasoline among humans have provided additional information on the effects of ingestion. But data on the acute effects in humans of skin contact and inhalation of vapors, the most common form of exposure (Reese and Kimbrough, 1993), are more scarce.

Human ingestion and inhalation of gasoline primarily affect the central nervous system (CNS) (Weaver, 1988; Reese and Kimbrough, 1993). Symptoms are similar to those of ethanol intoxication, including flushing, ataxia, staggering, slurred speech, confusion, blurry vision and headache; ingestion of high doses of gasoline may result in coma or sudden death (Reese and Kimbrough, 1993). Oral ingestion also causes inflammation of the gastrointestinal tract. Aspiration can cause fatal chemical pneumonitis in children. (Weaver, 1988).

Toxic levels of gasoline inhalation most frequently result from intentional sniffing. Sniffing produces an initial euphoria and relaxation, which may be accompanied by confusion, hallucination or psychosis (Maruff, 1998). Following the euphoric effect, subsequent symptoms may include nausea, vomiting, abdominal pain, anxiety, agitation, and hypomania (Reese and Kimbrough, 1993). An additional acute effect of gasoline inhalation is myocardial irritability and increased sensitivity to adrenaline, which may trigger an arrhythmia (Reese and Kimbrough, 1993). Because gasoline generally vaporizes on contact with skin, there is little toxicity associated with direct contact. However, prolonged or occluded contact may result in a chemical burn or "defatting" of the skin (necrosis of subcutaneous lipid tissue) (Weaver, 1988).

Several gasoline additives may produce harmful effects when ingested or inhaled at toxic levels. Ethanol is a common additive to gasoline, generally constituting about 10% of gasoline by volume (Caprino and Togna, 1998). Inhalation of ethanol may produce irritation of the eyes and mucous membranes, and at very high concentrations may induce CNS depression (Reese and Kimbrough, 1993). However, due to the widespread exposure of humans to ethanol in other forms, it is unlikely that the presence of ethanol in gasoline will significantly contribute to ethanol toxicity in humans.

Methanol is used as a gasoline additive or as a substitute fuel. While increasing the proportion of methanol in gasoline has been advocated as a means to cleaner emissions, there are significant health concerns about potentially increasing the incidence of methanol ingestion. Initially, ingestion of methanol may only lead to mild symptoms such as headache, nausea and dizziness. However, the liver oxidizes methanol into formaldehyde, which is then converted into formic acid, responsible for acute methanol poisoning. Severe methanol intoxication generally has a delayed onset while the methanol is metabolized, and eventually may lead to cyanosis, metabolic acidosis, visual impairment, coma or death (Caprino and Togna, 1998). Available data on human exposure to methanol fumes suggests that there is little risk of acute toxicity in humans from inhalation, even for those exposed to relatively high levels of methanol (Costantini, 1993). However, more data on the potential risks of increasing the methanol content of gasoline are needed.

The use of MBTE in gasoline has been growing in recent years, as oxygenation of fuels has been found to effectively reduce CO emissions. New studies have explored the possible health impacts of MBTE exposure. Animal studies show that inhalation of MBTE vapors may cause toxicity in rats and non-human primates, leading to transient ataxia and sedation (Costantini, 1993). MBTE has been used in humans to dissolve gallstones, and may be associated with hemolysis or necrosis (Reese and Kimbrough, 1993). However, because human exposure to MBTE for management of gallstones is significantly different than exposure to MBTE through gasoline, current data may not be applicable. When MBTE was first introduced to fuels in Alaska in 1992, there were increased reports of a variety of acute, non-specific symptoms, including eye and respiratory tract irritation, gastrointestinal distress, headache, dizziness and disorientation. Initial investigations suggested a link between exposure to MBTE and the development of symptoms, however subsequent studies among exposed workers, as well as controlled human experiments, have failed to show negative acute health impacts from exposure to MBTE in fuels (Caprino and Togna, 1998).

TBA is another gasoline additive intended to increase oxygen content and thereby decrease CO emissions. In humans, contact with volatile TBA has been found to produce irritation of the eyes and nose, and skin contact may result in dermatitis and defatting of the skin (Caprino and Togna, 1998).

Aromatic hydrocarbons (HCs) are natural constituents of, and additives to, gasoline, and may be absorbed through inhalation, ingestion or direct skin contact (although absorption through the skin is very slow). In cases of acute intoxication through ingestion or inhalation of benzene, toluene or xylene (aromatic HC's) the primary symptoms reflect CNS impairment. Mild symptoms may include dizziness, weakness, euphoria, headache, nausea and vomiting. Exposures to higher levels of the aromatic HCs may result in visual disturbances, tremor, rapid shallow respiration, hyperactive reflexes, ventricular fibrillation, convulsions, paralysis, and loss of consciousness. Inhalation may additionally result in irritation of the respiratory tract and pulmonary edema (Reese and Kimbrough, 1993). Direct skin exposure to aromatic HC's can result in defatting of the skin, with the severity depending upon the intensity and duration of exposure.

C. Chronic Toxicity

Chronic exposure to gasoline and its additives pose different health threats than does acute exposure. The illnesses associated with chronic exposure develop over a longer period of time, and may present themselves with more subtle clinical findings. The intervening time between exposure and outcome may obscure their relation, impeding the identification of the specific toxic agent or component of gasoline as the cause of the health outcome. Efforts to identify the causal link between gasoline and chronic outcomes have been challenged by limitation of study designs and the presence of possible confounders. Nonetheless, research has produced data implicating gasoline and certain additives in the pathogenesis of several illnesses.

One of the most researched subjects relating to gasoline toxicity is carcinogenesis. Benzene is toxic to bone marrow and exposure may result in luekopenia, lymphocytopenia, or aplastic anemia. Furthermore, benzene has been recognized as a cause of acute myelogenous leukemia (AML) in humans for more than sixty years (Huff et al., 1988). Further animal, human and mechanistic studies identified benzene as a strong carcinogen, capable of producing a wide variety of tumors following ingestion or inhalation (Maltoni et al., 1988). Epidemiological studies have demonstrated an increased risk of leukemia among groups with occupational exposure to gasoline, including tank truck drivers, land-based distribution workers and marine based distribution workers. The etiologic agent is presumed to be benzene (Infante, 1993; Enterline, 1993).

Multiple myeloma (MM) is another lymphopoietic cancer that has been linked to gasoline exposure. Epidemiological data showing an elevated risk of MM among people who have work-related exposure to hydrocarbons is limited by the rarity of the disease and the fact that it is often grouped together with lymphomas in cohort studies (Infante, 1993). Both MM and AML arise from cells within the bone marrow. Since benzene targets bone marrow, mechanisms suggest a role for benzene in the etiology of both illnesses.

Concern for a link between renal cancer and gasoline arose when animal lab experiments showed that long-term exposure to unleaded gasoline fumes resulted in a large excess of renal tumors in male rats (McLaughlin, 1993).

Subsequently a number of case control and cohort mortality studies set out to determine whether gasoline exposure posed similar risks to humans. Studies among refinery workers have shown little or no increased risk for developing renal cancer (Enterline, 1993). Gasoline distribution workers and tank truck drivers have higher levels of exposure to gasoline than refinery workers. However, among distribution workers and tank truck drivers, the findings have been mixed. Several case control studies have shown an elevated risk of kidney cancer among these groups (McLaughlin, 1993; Enterline, 1993), with some finding evidence of a dose-response relationship between hydrocarbon exposure and renal cancer (Infante, 1993). However, other case control and cohort studies have found no increased incidence of renal cancer among those with high levels of exposure to gasoline (Raabe, 1993; Infante, 1993). Many of the studies have been limited by methodological problems, such as potential recall bias or a lack of control of possible confounding variables such as smoking. Furthermore, the mechanism thought to be responsible for the development of gasoline-related kidney tumors in rats involves a protein that is not present in human kidney cells (Caprino and Togna, 1998). Further study is needed to determine if the risk of renal cancer observed in the male rats exposed to gasoline fumes is indicative of comparable risks in human beings.

Animal studies also suggest a possible increased risk of liver tumors among adult female rats exposed to high levels of gasoline (Caprino and Togna, 1998). However, cohort studies among humans have not found evidence of elevated rates of liver cancer among those occupationally exposed to gasoline. A study of refinery workers in Australia showed an increased incidence of malignant melanoma, raising questions about a possible link between gasoline exposure and skin cancer. Available evidence from that and other studies suggests that there is a link between malignant melanoma and working in refineries. However, it is unclear whether the risk is due to exposure to chemicals, UV radiation or some combination of the two (Infante, 1993). Further studies are needed to clarify this risk.

In addition to cancer, heart disease has been studied in connection with exposure to gasoline. Studies with myocardial infarctions and aortic aneurysms as outcome measures have had conflicting results. There may have inadequately controlled for variables such as smoking, since gasoline workers smoke less than the general population (Infante, 1993).

Another chronic health impact related to chronic gasoline exposure is CNS toxicity. Occupational exposure to gasoline has been associated with headache, fatigue, memory loss, and psychomotor and visual motor dysfunction (Burbacher, 1993). People who chronically sniff gasoline have been found to suffer from a variety of neurological symptoms such as ataxia, tremor, abnormal reflexes, cognitive defects and encephalopathic syndrome (Maruff et al., 1998; Burbacher, 1993). The magnitude of neurological defects depends upon the length of time spent sniffing as well as blood lead levels; some cognitive and motor defects persist among former gasoline sniffers (Maruff et al., 1998).

Several of the constituents of gasoline have been studied individually in humans or in animal models to determine their role in the CNS toxicity of gasoline. Available data on MBTE, ETBE and TAME do not provide evidence of risk of neurotoxicity in humans as a result of exposure to these compounds (Burbacher, 1993). Neurotoxic effects of butadiene or benzene in humans have not been reported (Burbacher, 1993). Xylene exposure has been found to lead to a reduced reaction time, decreased manual dexterity, disruption of body equilibrium, and EEG changes in humans (Burbacher, 1993). Toluene has been linked to ataxia and tremor among humans who are chronically exposed through toluene sniffing,with development of cerebral and cerebellar atrophy in severe cases. Occupational exposure to toluene may result in decreased manual dexterity and vigilance, as well as short-term memory deficits (Burbacher, 1993).

Several of the acute neurological toxicities associated with ethanol and methanol are discussed above. Chronic exposure to methanol may result in on-going symptoms similar to those of mild acute toxicity, including headache, dizziness, blurred vision and nausea. In addition, those who survive acute methanol intoxication may have motor symptoms similar to Parkinson's disease, thought to be the result of injury to the basal ganglia (Burbacher, 1993). Once again it should be noted that average exposures to methanol due to its presence in gasoline or use as a fuel do not approximate those required for acute toxic effect. The chronic neurological sequelae of ethanol are well described in humans, and may include ataxia, dysarthria, dementia, amnesia, peripheral nerve disorders, and lesions in the cerebellar and cortical regions of the brain (Burbacher, 1993). As in the case of methanol, the presence of ethanol in gasoline is unlikely to be responsible for a significant portion of ethanol intoxication or chronic neurotoxicity.

The gasoline additive that is perhaps best known for its role in neurotoxicity is lead. Lead contamination first became a major public health problem in the 1920s, when tetraethyl lead was added to gasoline to enhance its performance (Hernberg, 2000). The health impacts of lead exposure have been well described, involving insults to multiple body systems. Symptoms may include abdominal pain, irritability, lethargy, anorexia, pallor (due to anemia), ataxia and slurred speech. At high levels, lead intoxication may cause coma, convulsions and death. Chronic sub-clinical lead toxicity can significantly impair the developing nervous system of a young child, leading over time to decreased intelligence, disturbed neurobehavioral development, impaired growth, as well as decreased hearing acuity (CDC, 2001). Epidemiological studies suggest that the relationship between impaired cognition and lead-exposure follow a dose-response curve (Hu, 1998).

While the incidence of severe lead poisoning has decreased dramatically in recent decades in many countries where lead is no longer added to gasoline, exposure to lead continues to threaten the health of many people throughout the world -- particularly in many countries of the developing world where gasoline is still leaded (Tong et al., 2000). The presence of lead in gasoline poses a health threat to workers who face occupational exposures to gasoline, such as gasoline attendants (Ankrah et al., 1966). A "semi-occupational" exposure to lead was discovered in child and adolescent street vendors in Istanbul. Although lead additives to gasoline were decreased significantly there in 1989, the authors argue that intense exposure to emissions still results in high levels of lead exposure (Furman and Lalei, 2000). Exposure to high-traffic areas was identified as a risk factor for lead poisoning among children that live in countries where gasoline contains relatively high levels of lead, with supporting data from recent studies in Bahrain (Al-Mahroos and Al-Saleh, 1997), Indonesia (Heinze et al., 1998), Mexico (Romieu et al., 1994), and the Philippines (Sharma and Reutergardh, 2000). Children in many African countries are considered to be at high risk of lead exposure, since the gasoline sold in the region contains some of the highest levels of lead in the world (Tong et al., 2000).

VI. AIR POLLUTION

The combustion of fossil fuels has undeniably led to substantial pollution that is having environmental and human health impacts (Cifuentes et al., 2001). Air pollution provoked a national response in 1970 with the passing of the Clean Air Act (CAA).

This marked the first time that common air pollutants were all named and their known effects delineated. Since then, air pollution policies have significantly improved. Yet many of the harmful effects persist, and in some cases they are worsening.

A.The Pollutants

There are six main elements that contribute to air pollution. They are VOCs, NOxs, CO, particulate matter (PM-10 and PM-2.5), SOxs, and Pb. Burning fossil fuels, such as gasoline, oil,coal and natural gas, emits each of these pollutants. Each pollutant has characteristics that cause deleterious effects to property, environmental health, and human health.

VOCs

Volatile organic compounds, by definition, contain carbon, the basic element found in all living material. However, many VOCs do not occur naturally and are synthesized for various purposes. A unique feature of VOCs is that they are easily volatilized. Even at room temperature vapors readily escape from the liquid compounds into the atmosphere. Included in the category of VOCs are gasoline, industrial chemicals (such as benzene), solvents (such as toluene and xylene), and perchloroethylene (the principal dry cleaning solvent).

Although VOCs are also released from products such as paints, solvents, and glues, their primary source is the combustion of fossil fuels. Combustion of fuel by mobile sources is responsible for the majority of VOC emissions. In Los Angeles, California, mobile sources alone are responsible for 52% of VOC emissions. Globally, it has been found that mobile sources are responsible for 85% of benzene pollution (Anderson et al., 1998;Anderson et al., 2001).

NOxs

Nitrogen oxides in the atmosphere are primarily the result of burning fuels such as oil, coal and natural gas. **Burning diesel fuel, gallon for gallon, produces some 40 times the amount of NOxs as gasoline (HEI, 1995).** In the United States, mobile sources produce approximately 40% of all NOxs. Approximately 50% of NOx production is from electrical sources and a small percent is from industrial plants (Anderson et al., 1998; Anderson et al., 2001). NOxs released from mobile sources account for 72% of all NOx emissions in Los Angeles and 40-60% of all NOx emissions globally (Anderson et al., 1998;Anderson et al., 2001).

NOxs are precursors of Nitric Acid, one of the chemicals responsible for acid rain. NOxs also combine with VOCs to produce ground-level ozone or photochemical smog.

Note: the reaction of NOxs with VOCs is temperature-dependent.That is, more smog is generated on warm days.

SOxs

Sulfur dioxide, the principal SOx, is an odorless gas at low concentrations, but can have a very strong smell at high concentrations. SO_2 is a gas produced by burning coal, most notably in power plants. Mobil sources produce an estimated 4% of global SOxs (Anderson et al., 1998;Anderson et al., 2001). SOxs are precursors of sulfuric acid, another component of acid rain.

CO

CO is an odorless and colorless gas that is produced via the incomplete burning of carbon-based fuels. High concentrations can accumulate in enclosed spaces such as garages, poorly ventilated tunnels, and even along roadsides during heavy traffic (Behrendt et al., 1997). Los Angeles reports that mobile sources produce 96% of CO emissions, while global estimates are that mobile sources produce 70-80% of all CO emissions (Anderson et al., 1998;Anderson et al., 2001).

PM-10s

PM-10s are particles with diameters of around 10 microns or less (1 micron = one-millionth of a meter) that remain suspended in air for extended periods of time. Particulates are usually in the form of smoke, dust and vapors. There are many sources of PM-10s, including burning of diesel fuels by trucks and buses, mixing and application of fertilizers and pesticides, road construction on unpaved roads, industrial processes (such as steel making), mining, agricultural burning, and operation of fireplaces and woodstoves (Behrendt et al., 1997). Mobile sources produce an estimated 14% of global particulates (Anderson et al., 1998;Anderson et al., 2001).

PM-2.5s

PM-2.5s are particulates with diameters of 2.5 microns or less. They share the same sources as PM-10s, but research suggests that, because of their smaller size, they do more damage to lung tissue than PM-10s by penetrating into small airways and air sacs (alveoli).

Tetraethyl Lead

Lead has been used as an additive to gasoline to improve its performance as a fuel. The addition of lead to gasoline has decreased significantly throughout the world in recent decades because of harmful impacts on human health and is currently banned in several countries. However, much of the gasoline available in developing countries is still heavily leaded (see previous section).

The last twenty years have seen a volume of studies delineating the specific affects of air pollution on the world, including environmental effects, direct health effects and property effects. Findings have consistently shown that pollutants arising from fossil fuel consumption have serious and long-lasting negative effects.

B. Environmental Impacts

Many studies conducted in plants implicate the devastating effects of air pollutants. The principal component of smog, ground level ozone, is the result of a complex chemical reaction between VOCs and NOxs. Ozone causes a number of troubling symptoms for plant leaves. These symptoms include flecks, described as tiny light-tan irregular spots, stipples described as small, darkly pigmented areas, bronzing and reddening. All of these symptoms are consistent with plant injury. The type and severity of injury is dependent on a number of factors including duration and concentration of ozone exposure, weather conditions and plant genetics. However, all plants continuously exposed to ozone will demonstrate these effects and notably, they eventually become obscured by chlorosis and necrosis, and plant death (Brunekreef et al., 1997). In fact, the strongest evidence for significant effects of ozone on crop yield comes from studies showing that as seasonal ozone concentrations increase, crop yield decreases (Brunekreef et al., 1997). In addition, VOCs such as formaldehyde and ethylene are known to harm plants (Burnett et al., 1995).

In addition to direct effects on plants, pollutants from fossil fuel combustion contribute to significant changes in the atmosphere. Acid rain and global warming have subsequently emerged as serious threats to fort and agriculture (Rosensweig et al., 2001).

C. Human Health

Overwhelmingly, scientific literature shows that air pollution impacts human health. Studies have shown a positive correlation between pollutants such as those discussed above and mortality (California EPA, 1998; Choudhury et al, 1997; Devalia et al., 1994; Dockery et al., 1993; Dockery and Pope, 1994; Spix et al., 1998; Dockery, 2001; Peters et al., 2001), cardiovascular diseases (Edwards et al., 1994), respiratory diseases (California EPA, 1998; Edwards et al., 1994; HEI, 1995; IARC, 1989; IPCS, 1996; Katsouyanni et al., 1997), asthma visitations and hospitalizations (Whittemore and Korn, 1980; Devalia et al., 1994; HE, 1995; Kinney et al., 2000; Knox et al., 1997; Lipsett and Caplemann, 1999; Martens, 1998; McConnell et al., 1999; NIOSH, 1996) and reduced lung function (International Programme on Chemical Safety, 1996; Katsouyanni et al., 1997; Lipsett and Caplemann, 1999; NTP, 1998; Neas et al., 1999; Northridge et al., 1999; Ormstad et al., 1998; Ostro et al., 1991; Pekkanen et al., 1997). A recent study found a link to air pollution and lung cancer (Pope at. al., 2002).

A large subsection of this research addresses the effects of PM-10s. These microscopic particles cause nose and throat irritation, and lodge deep within lung tissue. But until recently their causative role in respiratory pathology remained unknown. Laden et. al (200) clearly demonstrated the harmful effects of PM-10s. A study by (Peters et al., 1997), from the Institute for Epidemiology and Inhalation Biology at Neuherberg, Germany, Peters et al.,(1997) assessed the effects of PM-10s on daily mortality rates in 20 of the largest cities and metropolitan areas in the United States from 1987 to 1994. The study found that PM-10s, such as dust and soot, contribute between 20 and 200 early deaths each day in America's largest cities and that fine particulate matter is associated with increased risk of death from cardiovascular and respiratory illnesses.

Asthma research has also focused on the health impacts of particulates. Asthma has been steadily rising in the U.S.. In 1980, an estimated 6.7 million Americans suffered from asthma. By 1994, that number had more than doubled; rising to 13.8 million. A study in Alaska showed that asthma visits were positively correlated with atmospheric concentrations of PM-10s (see figure 5) (HEI, 1995). Other studies demonstrate a positive correlation between symptoms of asthma and other respiratory disease and the proximity of residence to areas of major traffic (Pope 1989; Pope and Dockery, 1992; Pope et al., 1991; Peters et al., 1997; Peters et al., 1999). McConnell et. al. (2002) have shown that elevated ground level ozone levels may initiate new cases of asthma in children.

Quantitative knowledge of the health effects of particulate air pollution dates back to 1952. During one week in December of that year, a high-pressure system set in over London trapping coal emissions. Particle levels increased dramatically and then fell sharply over the week, while daily mortality showed a similar rise and fall (Dockery, 2001) (see Figure III).

In 1991, another high-pressure system set in over London. This time it was not coal emissions, but automobile emissions that were trapped in the atmosphere. During this episode, concentrations of nitrogen dioxide rose to record levels (twice the WHO guidelines), and were associated with moderate increases in particulate pollution. During that week there was a 10% increase in mortality and a 14% increase in cardiovascular disease. For the elderly, hospital admissions for respiratory disease increased by 19%, and by 43% for obstructive lung disease. These data were all statistically significant (Anderson et al., 1998). The landmark six cities study found that after controlling for other risk factors, mortality was 26% higher in the most polluted city versus the least polluted one (Dockery et al., 1993). Other studies demonstrate that even at much lower levels of pollutant gases (under U.S. ambient air quality standards and the guidelines set by WHO), there are significant health effects of air pollution (Pope et al., 1991; Schwartz et al., 1993; Schwartz and Dockery, 1992; Schwartz and Morris, 1995; Schwartz et al., 1996).

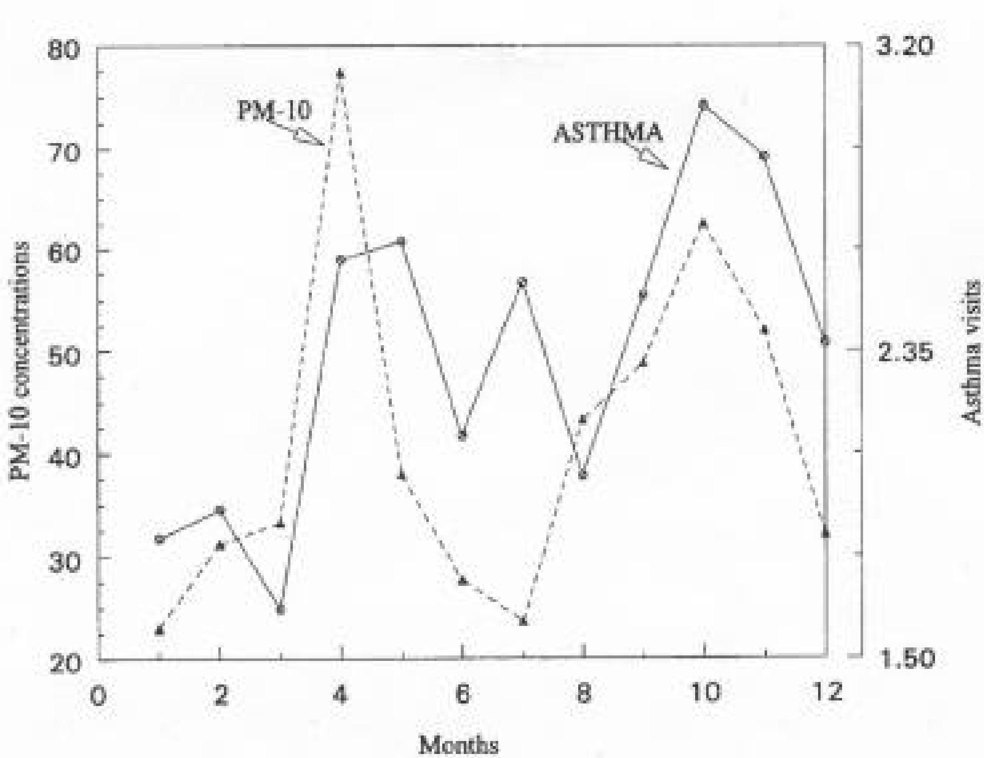


Figure 5: Average monthly asthma visits compared with PM-10 concentrations

Diesel engines are one of the most significant contributors to urban air pollution, accounting for 44% of the NOx emissions and 69% of particulate emissions from transportation. Researchers estimate that particulate pollution causes tens of thousands of deaths annually in the U.S. (Cifuentes et al., 2001). The impacts of diesel exhaust on lung function have been well studied (Rudell et al., 1996). Particulate matter is known to irritate the eyes and nose and aggravate respiratory problems including asthma, discussed earlier. Additionally, the PM-2.5s found in diesel exhaust have been directly associated with an increased risk of premature death. These particles absorb hundreds of chemicals onto their surfaces, including many known or suspected mutagens and carcinogens, as well as pollen grains (see below). Because of their size, these chemicals and allergens can penetrate deep into lung tissue.

Diesel exhaust (mostly from school buses and trucks) is often emitted in close proximity to where people live and work, intensifying the exposure in inner cities. More studies demonstrate the correlation between increased symptoms of asthma and respiratory disease and proximity to major roads or heavy traffic (Edwards et al., 1994; Brunekreef et al., 1997;Wissow et al., 1988). Diesel engines contribute significantly to the problem, releasing NOxs, SOxs, and particulate matter.

In its ninth annual report of suspected carcinogens, the National Institute of Environmental Health Sciences lists diesel exhaust particles as "reasonably anticipated to be human carcinogens" (HEI, 1995). Several national and international organizations regard particulates from diesel exhaust as a potential or probable human carcinogen. These organizations include the National Toxicology Program, the California EPA, the International Programme on Chemical Safety, the National Institute for Occupational Safety and the California Air Resources Board (California EPA, 1998; IARC, 1989; IPCS, 1996; NIOSH, 1996; NTP, 1998). The U.S. EPA is considering a similar classification. This classification is based on a growing number of studies demonstrating that exposure to high levels of diesel exhaust causes lung tumors in rats, and that humans who are routinely exposed to diesel exhaust have a higher risk of developing lung cancer. The California EPA estimates that 450 in every 1 million Californians are at risk of developing cancer because of exposure to diesel exhaust (California EPA, 1998).

Diesel particles and allergens

In addition to increasing the risk of respiratory disease, studies indicate that diesel exhaust particles can act as carriers of allergens, possibly aggravating allergies and asthma (Behrendt et al, 1997; Devalia et al, 1994; Knox et al., 1997; Ormstad et al., 1998; Takafuji et al., 1989). About 25% of the U.S. population suffers from hay fever or allergenic asthma. Several in vitro studies have demonstrated that many common allergens (grass pollen, cat, dog and birch pollen) will bind with diesel exhaust particles (Knox et al., 1997; Ormstad et al., 1998), suggesting a mechanism by which allergens can remain suspended in the air and enter into the lungs. Scientists believe that diesel exhaust plays a major part in exacerbating allergies and allergenic asthma in our cities.

In addition, ragweed plants grown in elevated carbon dioxide conditions (700ppm) produce 61% more pollen than those grown at current levels (360ppm) (Wayne et al., 2002).This is consistent with other studies (Ziska and Caulfield, 2000).With the potential for increasing amounts of pollen as a result of increased carbon dioxide levels and continued use of diesel, more pollen-diesel particles can be generated and deposited into the lungs.

Finally, because air pollution, and particularly diesel exhaust, is most prevalent in cities, urban residents will experience the most severe impacts. Moreover, within cities, the highest density of buses and bus stations are found in the poorest neighborhoods, and poverty, race and asthma rates are positively correlated (Weiss and Wagener, 1990). In the early to mid-1980s, for example, the asthma mortality rate among black residents of the United States, aged 5 to 34 years, was three to five times as great as the rate among whites. A study done in 1992 found that asthma hospitalization rates for the city of Boston were 4.2 per 1,000 residents; twice the state rate of 2.1/1,000. Moreover, within Boston, the asthma rate varied significantly, from a low of 0.7/1,000 persons in the Kenmore Square area to a high of 9.8/1,000 in Roxbury (Gottlieb et al., 1995) (See Figure 3.)

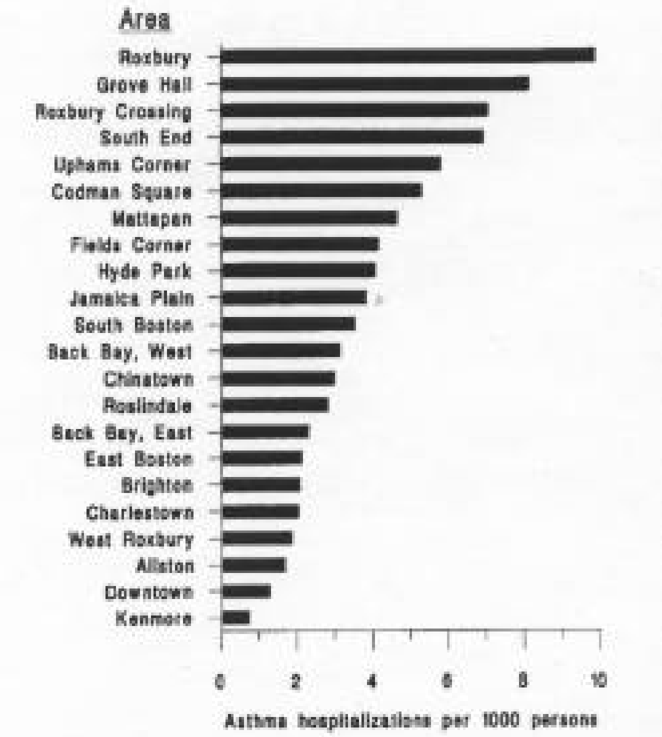


Figure 6: Age- and gender-adjusted asthma hospitalization rates in Boston (from CHEST 108(1):28-35 (Jul 1995)

Other air pollutants have significant health effects as well. There is a growing body of evidence indicating that some VOCs, specifically benzene, are cancerous (Hayes et al., 1996; Behrendt et al., 1997). The physiologic effects of CO have long been understood. CO reduces the ability of the heme molecule in red blood cells to carry oxygen and exposure to CO is especially hazardous to people with cardiac, respiratory and vascular disease.

VII. ACID RAIN

As early as 1852, acid rain was recognized to be a consequence of fossil fuel combustion, yet it continues to plague the world, particularly in industrialized nations. Acid rain causes an array of problems now known to be much more complex and diverse than previously believed. The impacts of acid rain are no longer considered as isolated effects, but are recognized to impact entire ecosystems. The growing understanding of acid rain's complexity and its ongoing driving forces bring into question the extent of anticipated benefits of current control efforts.

Sulfur dioxide (SO_2) and nitrogen oxides (NOx) released from the combustion of fossil fuels have been found to be the leading contributors to acid rain production. As both SO_2 and NOxs enter the atmosphere, they become oxidized into sulfuric acid and nitric acid respectively. The reactions are enhanced in areas of increased pollution as ammonia and ground level ozone act as catalysts. These acids dissolve readily into water and help form acidic water droplets, returning to the earth in the form of acidic rain, snow, or fog. Natural rainwater has an inherent acidic pH of 5.6. But acid rain commonly reach pH levels as low as 4, about 40 times the acidity of natural rainwater.

Once acid rain returns to the surface, it begins a cascade of harmful environmental effects. The consequences of acidic precipitation are complicated by the relationships within ecosystems. From terrestrial to aquatic environments, the individual effects are each detrimental.

A. Terrestrial Effects

Upon reaching the ground, acid rain begins to take immediate effect in soils. Natural rainwater's slight acidity is normally countered by soil buffering capacity. This buffering capacity plays an integral part in the ecosystem, allowing for tolerance within a range of fluctuating conditions. Cations such as Ca^{++} (calcium), Mg^{++} (magnesium), and K^{+} (potassium) neutralize acidity in the soil. As the concentration of these cations increases, the buffering capacity of soil correspondingly increases, raising the range of soil's acidic tolerance. Acid rain overwhelms soil's buffering capacity, disrupting carefully established pH balances.

One consequence has been the leaching of base cations from soil. Long-term studies show that prolonged exposure to acid rain causes decreased levels of calcium and magnesium in soils. The increased acidity of soil dissolves the cations, allowing drainage waters to wash them away. An increased level of these cations in nearby stream waters further strengthens evidence of this leaching process (Likens et al., 1996). The soil develops mineral and nutrient deficiencies with the loss of these base cations.

The increased acidity also helps to mobilize aluminum in soils. Aluminum is normally benign in its organic form, but as it becomes dissolved in the acidic soil, it converts to an inorganic form. In this form, aluminum becomes toxic to vegetative growth through several mechanisms. First, aluminum decreases the availability of calcium by displacing adsorbed calcium and increasing the susceptibility of the calcium to leaching (Lawrence et al., 1995). Second, aluminum decreases the efficiency of calcium uptake by plant roots. Aluminum's higher affinity for negatively charged binding sites allows it to out-compete calcium for root absorption. Consequently, soils with calcium to aluminum ratios of less than one are at risk for aluminium toxicity (Cronan and Grigel, 1995). Even soils with ratios above one are at risk as continued leaching of base cations causes soils to shift toward lower calcium to aluminum ratios. Finally, at high enough concentrations, aluminum has been shown to adversely affect plant life through direct toxicity to roots (Anderson, 1988).

Beyond changes in soil chemistry, acid rain negatively impacts the growth of trees. Research focusing on the dieback or reduced growth and mortality of trees has found strong associations with acidic deposition. The red spruce, native to Maine, suffered from significant dieback in the 1970s and 1980s. Greater than 50% of trees died in the higher elevations of the Adirondack and Green Mountains. This immense dieback has been linked to increased acidic deposition in several ways. Red spruce needles lose some of their cold tolerance after acidic mist or cloud exposure, increasing their susceptibility to death during winter (DeHayes et al., 1999). Low calcium to aluminum in the soils of the red spruce have likely caused nutrient deficiencies as the aluminum blocks calcium uptake (Shortle and Smith, 1988). One report indicates a link between calcium to aluminum ratios of less than one and impaired growth in greater than 50% of the red spruce (Cronan and Grigal, 1995).

Studies of the episodic dieback of the sugar maple in the Northeast have also shown associations with acidic precipitation. Seasonal deficiencies of base cations such as calcium and magnesium were found to correlate with the episodic timing of the diebacks (Horsley et al., 1999).

The red spruce and sugar maple are just two examples of the negative impacts of acid rain on vegetation. The soil changes that initiate these effects are found in other areas and among other plant species. It is difficult to overestimate the importance of plant life on earth. An integral part of the food web, plants support all life, provide food, and filter atmospheric gases; and help to alleviate greenhouse gas buildup.

B. Aquatic Effects

Once acid precipitation saturates the soil's buffering capacity, runoff and drainage play a large role in the spread of acidification. Aquatic systems such as lakes, streams and groundwater are all susceptible. Soil runoff not only lowers the pH levels of aquatic bodies, but also exposes them to increased levels of aluminum.

Acidification of surface waters occurs in two broad ways: episodic acidification and chronic acidification. Episodic acidification usually occurs in response to seasonal changes, particularly the onset of spring. Ecologists consider springtime snowmelts to be the major contributor. Studies of streams in the northeastern United States have demonstrated shifting levels of pH, nitrate, and aluminum in correspondence with seasonal shifts (Wigington et al., 1996). The effects of chronic acidification have been difficult to ascertain given the need for data dating back to the Industrial Revolution and the need for several years of data collection. However, use of acidification models that utilize current emission data and projected historical data have demonstrated a significant level of chronic acidification over the last 150 years (Driscoll et al., 2001).

Acidification of bodies of water affects the vast the array of aquatic organisms that live in aquatic systems. Changes in pH, nitrate concentration, and aluminum concentration shifts the natural balances established within an ecological system. While some organisms are able to flourish under such conditions, others are harmed. The susceptibility of fish in these changing environments has been clearly documented. Studies show both low pH and aluminum are toxic to fish (Baker and Schofield,1982). Acid-sensitive species are at greatest risk and are the first to be eliminated in aquatic environments. Studies have shown significantly fewer species of fish in lakes with decreased pH (Schindler et al., 1985). Episodic acidification has been particularly associated with larger amounts of fish loss in streams and rivers. These water bodies are more sensitive and more susceptible to large and abrupt changes from snowmelts, having smaller refuge areas for fish. Episodic acidification also impacts fish mortality, migration and reproductive failure, further reducing fish populations (Baker et al., 1996).

Studies show that acid rain impacts a wide variety of species across the food web, particularly among the egg and younger stages of development. Lower pH has been linked to decreased hatching and weaker eggs of species such as water mites and aquatic insects (Rousch et al., 1997). These organisms play an integral role in the food web and in the predation of mosquitoes, and their loss jeopardizes the sustainability of entire ecosystems.

Although many species suffer the effects of acid rain, some “weedy species” thrive in it. Changes in environmental chemistry and biodiversity have given some organisms a window of opportunity to flourish. Harmful algal blooms (HABs) have disrupted marine environments such as the Chesapeake Bay, Indian Ocean, and Bay of Bengal. Rain carries nitrogen and phosphorus from sewage and fertilizers into surrounding streams, estuaries, and eventually into coastal waters, providing a rich environment the algal growth. Nitrates produced from acid rain deposition also contribute significantly to the nitrogen loading of water bodies; 20 to 35% of the Chesapeake Bay's controllable nitrate loads have been linked to NOx emissions and their resulting acidic deposition (Dennis, 1997). The explosion of algae, the algal "bloom," can have a variety of environmental effects. Overgrowth clouds the water decreasing sunlight penetration, harming aquatic vegetation and animals that need sunlight to survive. Once algae die, they settle to the bottom where they decay, a process that consumes vital oxygen. This causes so-called "dead zones." Eutrophication contributes to HABs that lead to shellfish poisoning and algae and zooplankton can harbor pathogens (Epstein et al., 1993) Eutrophication can also lead to coral reef degredation and collapse of food webs (EPA, 2001)

C. Acid Rain Recovery

In 1970, the Clean Air Act instituted emissions standards that could not be met with existing technologies while imposing stiff penalties for failures to comply with these standards (Hunter et al., 1998). Bemoaned by industry, this 'technology-forcing' legislation is credited with providing the incentives and disincentives required for significant cuts in emissions. Sulfur dioxide reductions have been exemplary, having surpassed the 50% decrease goal stated as part of the Acid Deposition Control Program. Theoretically, decreased acid rain deposition should help promote ecosystem recovery. Signs of recovery had been demonstrated in several lakes and streams in Maine through increased alkalinity But the same study reports ongoing acidification despite the decline in levels of SO_2. The study concluded that significant loss of base cations from the soil and increasing levels of nitric acid in precipitation contributed greatly to continuing acidification (Stoddard et al., 1999). Because of these pervasive forces, aquatic recovery will likely be slower than originally anticipated. Similarly, studies of forest soil recovery have shown continued susceptibility to acidic deposition and evidence of delayed recovery (Likens et al., 1996).

Although the Clean Air Act has made strides in reducing the effects of acid rain, more is needed to advance the recovery process. Adding alkaline limestone to aquatic systems, a process called liming, can help counter the affects of acidification by neutralizing acid. The process requires multiple treatments and is quite expensive, but it does sustain aquatic organisms for the short term. Extensive use of liming has contributed to accelerated recovery in Sweden.

The costs of liming are high and alternative efforts can focus on stronger emission reductions. The Clean Air Act was successful in reducing SO_2 emissions but did not cap the emission of NOx gases. The contribution of NOx gases to acid rain and eutrophication is increasing as fossil fuel dependence grows.

VIII. GREENHOUSE GASES AND GLOBAL WARMING

A. Introduction

The greenhouse effect describes a natural phenomenon -- the capacity of certain gases in the atmosphere to trap heat emitted from the Earth's surface. This naturally occurring and constantly evolving mechanism has provided insulation that warms the earth's surface. Without the thermal blanket provided by the greenhouse effect, Earth's climate would be about 33ºCelsius (60ºF) colder than it is today;too cold for most living organisms to survive (Encarta®, 2001).

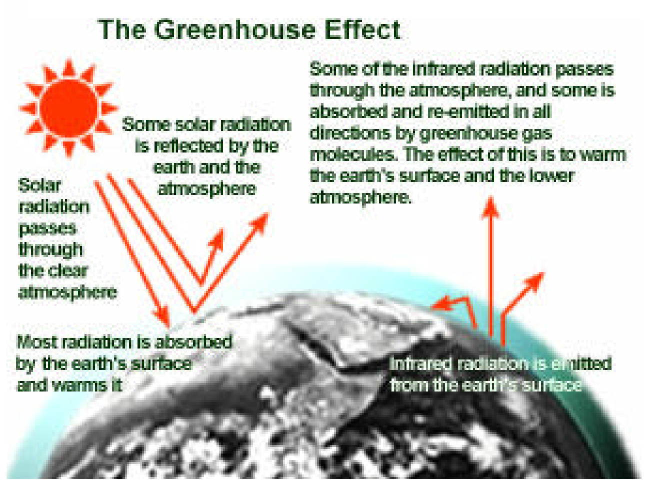
Over the last twenty years there has been increasing concern that human activities, namely the burning of fossil fuels plus changing land use and clearing for agriculture and livestock are modifying the natural atmospheric processes that maintain surface temperatures (Watson et al., 1997). These atmospheric gases are now at levels higher than they have been in the last 420,000 years (Petit et. al, 1999). As the gases build up in the earth's atmosphere, they trap more heat and ultimately raise the Earth's temperature at a rate far greater than any natural change since the beginning of agriculture 10,000 years ago (McMichael and Haines, 1997).

The unnatural warming of the earth is referred to as global warming. The Intergovernmental Panel on Climate Change -- a multidisciplinary body established by the United Nations -- forecasts an estimated 1.4-5.8 degrees Celsius increase in the Earth's surface temperature over the next 100 years (IPCC, 1996). The projected temperature rise this century was increased substantially in the most recent Third Assessment (IPCC, 2001a). Disturbances to ecological systems are projected to negatively impact global public health, especially in developing countries, with the aftershocks felt in economies worldwide (IFRC&RC, 1998; Epstein, 1999; Epstein, 2000).

B. The Greenhouse Effect

The interaction of sunlight with certain gases in our atmosphere leads the greenhouse effect. As the sun's radiation hits the earth's atmosphere, 25% of the energy is radiated back into space and approximately 20% is absorbed; the upper atmosphere absorbs gamma rays and ozone absorbs ultraviolet light. The remaining 50% of the sun's energy reaches the earth's surface. Oceans, plants and soils absorb almost 85% of this heat energy, while the rest is reflected back into the atmosphere, predominantly by snowcaps, ice-sheets and deserts. Atmospheric greenhouse gases trap some of this outgoing energy, retaining heat and, in turn, emitting infrared radiation back into the atmosphere. This heat energy is absorbed by greenhouse gases and warms the lower atmosphere (EPA, 2001b; Factmonster.com, 2001).

Figure 7: The Greenhouse Effect (Image from EPA)



Without this natural greenhouse effect, heat energy absorbed and reflected from the earth would be lost into space and surface temperatures would be much lower, about zero degrees Fahrenheit (-18ºC) rather the present 60°F (~15°C) (NCDC, NOAA, 2001). However, increasing concentrations of atmospheric greenhouse gases enhances the atmosphere's capacity to retain infrared radiation, creating an artificial warming of the earth's surface and lower atmosphere (the troposphere, extending ~8 km from Earth's surface).

History

Scientists first began investigating the greenhouse effect in the 1800s. But in 1957, the first International Geophysical Year, researchers from the Scripps Institution of Oceanography, California began monitoring carbon dioxide levels in the atmosphere on Mauna Loa in Hawaii. They subsequently found that carbon dioxide concentration was increasing every year. These findings were later confirmed worldwide, motivating scientists to examine more closely at the potential risk of human-induced climate change. In 1988 the United Nations Environment Programme, in collaboration with the World Meteorological Organization, formed the Intergovernmental Panel on Climate Change (IPCC). The IPCC has produced three assessment reports on the science and impacts of climate change, and, in other reports, explores policy options for controlling greenhouse gas emissions.

In 1992 at the Earth Summit in Rio de Janeiro, Brazil, the IPCC played a fundamental role in the development of the most comprehensive environmental treaty ever drawn: the United Nations Framework Convention on Climate Change (UNFCCC). The treaty set out a plan of action for the control of greenhouse gas emissions. A protocol established in 1992 was modified and adopted in 1997 at the Third Conference of the Parties held in Kyoto, Japan. This agreement outlines practical steps for reducing the world's dependence upon fossil fuels. Under the Kyoto Protocol the Parties agree to decrease the overall emission of greenhouse gases to an average of 5.2% below levels in 1990, with deadlines ranging between 2008 and 2012. Individual reduction percentages for countries reflect the capacity for that country to reduce its emissions, while considering its potential for economic growth (Eddis, 2001; Sheridan, 2001).

In November 2000 the Sixth Conference of the Parties of the UNFCCC met in The Hague with the intent of enacting the guidelines outlined in the Kyoto Protocol. Without U.S. agreement, the Parties failed to reach a consensus (Lowen, 2000). In July 20001, the Kyoto protocol was agreed upon by over 160 nations, though the U.S. did not agree to participate.

The Greenhouse Gases

Atmospheric greenhouse gases (GHGs) are both naturally occurring and human-made. The most abundant natural greenhouse gas is water vapor, followed by carbon dioxide, methane, nitrous oxide, ozone and CFCs. GHGs can contribute to the greenhouse effect directly -- when the gas itself absorbs outgoing infrared radiation -- or indirectly, when a chemical transformation produces a gas that has the properties of a greenhouse gas (e.g., ground-level ozone), or when the gas influences the atmospheric lifetimes of other gases (e.g., warming increases the holding capacity of water vapor).

·**Carbon dioxide** is released into the atmosphere when wood and wood products, solid wastes and fossil fuels such as oil, coal and natural gas are burned. Also, deforestation releases stored carbon and reduces the natural "carbon sink."

The Carbon Cycle

Approximately 5.5 Gigatons (billion tons) of carbon is released by burning fossil fuels each year. Changes in Land Use/Land Cover contribute another ~1.5GtC/year.Thus the total is ~7GtC/y. The ocean absorbs ~2 GTC/y; the terrestrial biosphere another ~ 2GtC/y. This leaves ~3 GtC to accumulate yearly in the atmosphere.

Ice core records from Antarctica show that CO_2 levels have held between 180 parts per million and 280ppm for the past 420,000 years (Petit et al., 1999). Feedbacks in the global carbon cycle -- including the ocean and terrestrial sinks -- may have helped maintain levels within these two boundaries. The lower levels have accompanied Ice Ages and the higher levels have accompanied warm, interglacial, periods. Today, we have exceeded these levels with atmospheric CO_2 concentrations of 360ppm, apparently overwhelming the buffering capacity of the biological sinks to take up C. Changes in land cover and soil composition (e.g., acidification) may further alter the terrestrial sink, and ocean warming may reduce its capacity to take up CO_2.

·**Methane** is emitted during the production and transport of oil, natural gas and coal. Decomposition of organic wastes and livestock also produce methane.

·**Nitrous oxide** is released during agricultural and industrial activities as well as during combustion of solid waste and fossil fuels.

> *The Nitrogen Cycle*
>
> Approximately 100 million metric tons of N from the atmosphere is "fixed" by plants and soil fungi. The chief anthropogenic sources of N are a) fertilizers, b) animal waste (human, hog and cow) and c) the burning of fossil fuels. These sources together have doubled the amount of N going into soils, the aquatic and marine environments. The chief results are a) increased GHG warming, b) acid precipitation, and c) eutrophication from sewage, fertilizers, and fossil fuel combustion.

·**Chlorofluorocarbons** (CFCs), **hydrofluorocarbons** (HFCs), **perfluorocarbons** (PFCs), and **sulfur hexafluoride** (SF6) are generated from a various industrial processes.

Each greenhouse gas differs in its ability to absorb and trap heat in the atmosphere. Human-made chemicals are the most heat-absorbent. Methane and NOxs trap over 20 and 250 times more heat respectively per molecule than carbon dioxide. Estimates of greenhouse gas emissions are measured in units of millions of metric tons of carbon equivalents (MMTCE), classifying each gas by its global warming potential (GWP) value (IPCC. 1996, 2001; EPA, 2001b). The concept of a GWP permits a comparative assessment of the ability of a greenhouse gas to trap heat in the atmosphere relative to another gas. Consistent with the IPCC guidelines, carbon dioxide has been used as the reference gas (McMichael et al., 1996). The GWP of a greenhouse gas as listed below is the ratio of global warming from one unit mass of a greenhouse gas to that of one unit mass of carbon dioxide over a time period of 100 years.

The atmospheric concentration of GHGs has steadily increased since the mid-1800s. Three gases account for the majority of the enhanced heat-trapping capability of the earth's atmosphere.

Figure 8: Global Warming Potentials (GWP) over 100 Years

GAS	GWP
Carbon Dioxide	1
Methane	21
Nitrous Oxide	310
HFC-125	2,800
CF4	6, 500
C2F6	9,200
HFC-23	11,700
SF6	23,900

Carbon dioxide levels have increased by 30%
Methane levels have increased by 145%
Nitrous oxide concentrations have increased by approximately 15%
(EPA, 2001b; EIA, 2001).

C. GHG Emissions

The primary GHG emitted through human activities is carbon dioxide. Prior to the Industrial Revolution, the decomposition of organic matter and other natural systems produced 10 times as much CO_2 as human activities. In 1998, combustion of fossil fuels accounted for 98% of the total U.S. CO_2 emissions, 24% of methane emissions, and 18% of NOx emissions. Increased agriculture, deforestation, industrial manufacture and mining further contributed to emissions. **In 1997, the United States, with 4% of the world's population, was responsible for one-fifth of total global GHG emissions (McMichael and Haines, 1997)**. In an effort to combat the growing impact of global emissions, emission inventories were devised to account for the amount of air pollutants released into the atmosphere. These inventories are used by scientists to develop air quality models, by policy makers to develop strategies and by governments to ensure compliance with emission limits.

Activities related to energy are responsible for nearly all the CO_2 emissions in the U.S. between 1990 and 1998. In 1998, the burning of fossil fuels accounted for almost 85% of the energy expenditure in the U.S., while only 15% came from other energy sources. Four end-sector industries are primarily responsible for contributing to carbon dioxide emissions from the combustion of fossil fuels; industrial activities accounted for 33% of emissions, transportation for 31%, residential for 20%, and commercial activities accounted for 16% (EPA, 2001b).

Combustion of fossil fuels releases carbon dioxide into the atmosphere because of the high quantity of carbon stores within the fuels. Coal produces the largest amount of carbon dioxide per unit of energy generated, followed by petroleum and natural gas. Petroleum, however, is the most common source of fossil fuel energy in the U.S., accounting for 39% of the total energy consumption in the U.S. in 1998 -- primarily for transportation. From 1990 to 1998 CO_2 emissions increased in the U.S. an average of 1.3% annually. The booming economy of the 1990s, the low price of fossil fuels and the increased use of fossil fuels by electric companies all increased the consumption and CO_2 emissions (EPA, 2001b).

Estimates of future emissions and concentrations depend upon a number of factors, including demographics, policies, economic development and technological and institutional trajectories (Haines et al., 2000). It has been projected that, by 2100, in the absence of emission control policies, levels of carbon dioxide will be anywhere between 30-150% higher than current levels (IPCC, 2001a).

D. The Changing Climate

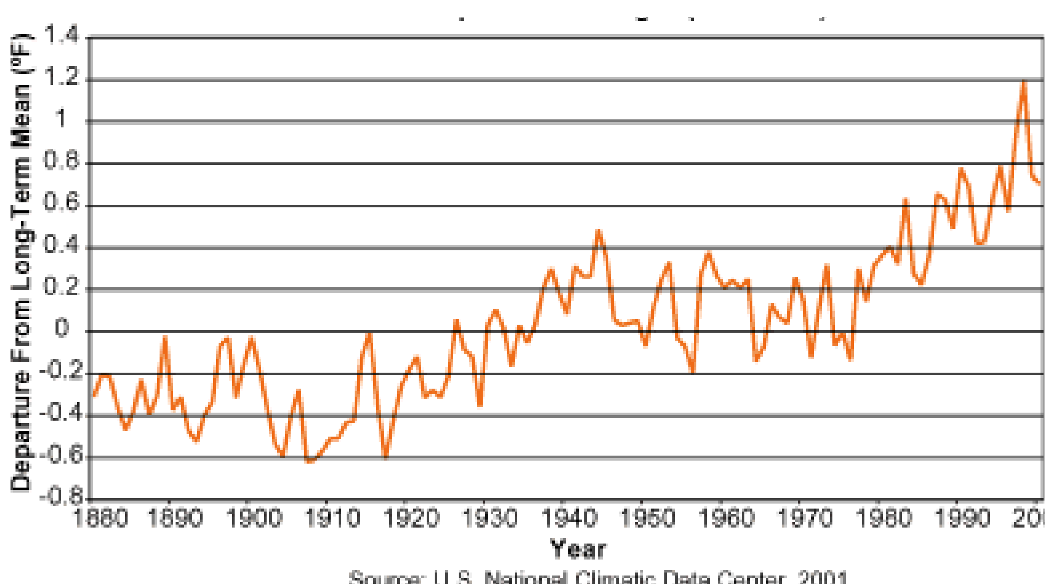
Since the late 1800s Earth's temperature has increased about 0.6°C, and 0.2 to 0.3°C during the past 25 years. Increasing concentrations of GHGs are projected to accelerate the rate of global climate change. Warming of the earth has not been uniform across the continents -- some areas like the southeastern U.S. have become cooler, while temperatures have increased over northern North America and Europe. Arctic and Boreal regions (Canada and Siberia) are warming faster than temperate and tropical zones (IPCC, 2001b). The 10 hottest years of the past 100 years have occurred in the last 15 years. Of the ten years, 1998 was the warmest year on record (EPA, 2001b; NCDC, NOAA, 2001).

Scientists have predicted that the global surface temperature could rise 1-4.5°F (0.6-2.5°C) in the next fifty years, and 2.2-10.4°F (1.4-5.8°C) in the next century, with significant regional and national variation (IPCC, 2001a).

Since 1950, winter and nighttime temperatures (minimum temperatures or TMINs) have increased at twice the rate as overall warming (Easterling et al., 1997); a change that has already affected the timing of seasons and the distribution of flora and fauna on land and in the ocean (IPCC, 2001b).

Indirect indicators of warming, such as borehole temperatures, decreased floating ice in the Arctic Ocean (Rothrock et al., 1999; Parkinson et al., 1999) and snow cover in the Northern

Figure 9: Global Temperature Changes 1880-200



Hemisphere, glacier recession data, a global sea level rise by 4-8 inches over the past century and the increase in worldwide precipitation are evidence of climate change (IPCC, 2001a&b).

In addition, extreme weather events (chiefly, droughts and heavy rain) have increased in intensity and are projected to increase in frequency (IPCC, 2001a). The long-term effects of climate change on global temperatures and weather patterns, and the resulting impacts on human health, are attracting increasing attention in the fields of international, public and environmental health medicine (NCDC, NOAA, 2001; IPCC, 2001b). The changes in the intensity and frequency of weather extremes may hold the most profound impacts for agriculture, societal infrastructure, economies, ecosystems and human health (IPCC, 2001b).

E. Health Impacts

Global climate change is projected to have a diverse range of impacts on human health, with the negative impacts expected to outweigh the positive ones. Climate change is already affecting ecological and social systems, creating conditions conducive to expanding the range and intensity of infectious disease outbreaks. Prolonged droughts have altered food production and contributed to population displacement, while intense flooding has altered economies.

There are many variables in quantifying how climate change will impact human health. Social factors (poverty, poor nutritional status and crowding), along with ecological change (deforestation and loss of coastal wetlands), render many developing countries particularly vulnerable to extreme weather events and subsequent outbreaks of infectious diseases (IPCC, 2001b). Aging populations in industrialized nations face other health risks, particularly from growing temperature and precipitation extremes (heat and cold, rains and ice storms) (Woodward et al., 1998). Variations in climate change from region to region suggest that the impacts on human health will take both direct and indirect pathways (McMichael et al., 1996; McMichael and Haines, 1997; Haines et al., 2001).

Direct Effects

Direct health effects include increases in heat related mortality and morbidity from illnesses associated with heat waves and thermal stress, principally affecting the elderly and the urban poor (McMichael and Haines, 1997; EPA, 2001c; Last and Wallace, 1992).

Meteorological findings suggest that elevated nighttime temperatures are the most significant factor contributing to heat-related mortality. Studies predict a three to four-fold increase in heat-related mortality in large U.S. cities if carbon dioxide levels were to double, likely in the absence of emission controls (Patz, 1995).

While warmer winters may decrease cold-related mortality in many temperate countries (IPCC, 2001b), increased variability in temperatures in summer and winters may have the greatest impacts on mortality (Braga et al., 2001).

Extreme weather events, such as intense rainfall (>2 inches/day is the NCDC, NOAA index) can lead to increased runoff and thus exposure to chemicals, nutrients and microorganisms in water supplies, as well as physical damage, food shortages, population displacement, and death. Damage to communities can then have psychological and economic impacts. Severe weather systems can also create conditions conducive to clusters of infectious disease outbreaks as a result of flooding, standing water, water contamination and loss of freshwater availability following the initial insult, increasing mortality and morbidity (Epstein, 1999).

In recent years, a number of severe climate-related disasters adversely affected human health -- including floods in China, repeated floods in Mozambique, Bangladesh and parts of Europe, and record flooding in Central America in November1998 accompanying Hurricane Mitch (Epstein, 1999). In 2001, prolonged droughts affected Afghanistan and Iran, Mongolia and Sri Lanka, and many other parts of the developing and developed world. These climatic events illustrate how populations with few resources, lacking the necessary infrastructure essential to mobilize relief efforts, are more susceptible to the adverse effects of severe weather (IPCC, 2001b; Haines et al., 2001).

Increased rainfall and warmer temperatures can increase molds. The same conditions allow trees to produce more seeds than usual (DeLucia et al., 1999). Increased CO_2 itslef causes lobholly pine to increase seed and cone production (LaDeau and Clark, 2001). Increased levels of pollen are produced from ragweed with increased levels of CO_2 (Wayne et al., 2002). The highest pollen count recorded (over 6000 grains per cubic meter; alerts being issued with levels over 250g/m3) was recorded in New York in May 2001 (Daley, 2001).

Indirect Effects

Indirect effects on biological systems may be of even greater consequence for human health.These impacts include:

- •Increased transmission of vector-borne infectious diseases
- •Increasing populations of water-borne pathogens
- •Decreased agricultural productivity
- •Social disruption, economic decline and population movements
- •Sea level rise

Infectious Diseases

One of the major impacts of climate change for infectious diseases may be felt through the influence on the vectors (carriers) that spread malaria, dengue fever, leishmaniasis, viral encephalitides and schistosomiasis (Patz et al., 1996; Rogers and Packer, 1993). Infectious parasites and viruses that cycle through cold-blooded insect vectors to complete their development are highly susceptible to subtle changes in the climate. In temperate regions, alterations in climate could affect vector-borne diseases by increasing the vector's reproductive and biting rates, as well as the rate of pathogen development within the vectors (Martens et al., 1997).

An increase in temperatures create the *conditions conducive* to the transmission of key vector-borne diseases to extend to higher altitudes, affecting immuno-susceptible highland populations to new diseases.

Such changes are already being observed in highland regions, where plant communities are migrating upward, glaciers are rapidly retreating and the level at which freezing occurs all year round (the freezing isotherm) has moved up ~500 feet or close to 2ºF warming in the past three decades (Epstein et al., 1998). Highland areas are particularly sensitive gauges of changing isotherms. Studies of ticks suggest that conditions conducive to transmission have begun to shift in latitude as well (lindrigan and Gustafson, 2001)..

Higher temperatures, in combination with altered rainfall patterns, may also prolong transmission seasons along the southern and northern margins where these diseases currently circulate. The impact of these diseases will depend upon the level of economic development, public health infrastructure and previous exposure of the population in the newly affected areas. Compounding the new geographical reach of infectious diseases are the existing social patterns of health care access --- those most vulnerable are those who have limited or inadequete services (Patz, 1995; McMichael and Haines, 1997; EPA, 2001c).

The current geographic range of malaria is generally limited to the tropics and subtropics since the Plasmodium parasite requires an average temperature above 16°C to mature (Martens et al., 1997). Malaria has been observed in non-endemic exposing populations at high elevations in Zimbabwe, Rwanda and Ethiopia during unseasonably warm conditions, populations previously protected because of their altitude (Loevinsohn, 1994; Tulu, 1996). Today, one-half of the world's population is exposed to malaria on a daily basis. Deforestation, drug resistance and inadequate public health measures have all contributed to a recent resurgence. Warming and extreme weather add new stresses. Dynamic models project that the warming accompanying the doubling of atmospheric CO_2 could increase the transmission capacity of mosquitoes some 100-fold in temperate zones, and that the area capable of sustaining transmission will grow from that containing 45% of the world's population to 60% (Martens et al. 1997). Statistical modeling projects less of a change (Rogers and Randolph, 2000). Notably all these analyses rely on average temperatures, rather than the more rapid changes in minimum temperatures being observed, and thus may underestimate the biological responses.

Increased temperatures also drive the dynamics of dengue fever. Warmer water temperatures found in mosquito breeding vessels reduces the size of the emerging adult, forcing female mosquitoes to feed more frequently to develop a viable egg batch, increasing exposure to humans. Viral development time inside the mosquito also shortens with higher temperatures -- increasing the proportion of mosquitoes that become infectious at one time (Patz et al., 1996).

The diseases that are most likely to be affected by climate change in temperate regions include malaria, dengue fever, viral encephalitides, and Lyme disease. With profound changes in the temperature, malaria may breach existing public health interventions and bring malaria back to Europe (McMichael and Haines, 1997).

Water-Borne Pathogens

Global warming also raises sea surface temperatures, leading to higher incidence of water-borne cholera and shellfish poisoning. Marine phytoplankton blooms proliferate in warmer waters, provided sufficient nutrients (Harvell et al., 1999). *Vibrio cholerae* has been found to correlate with warmer sea surface temperatures as marine zooplankton and blooms are natural reservoirs for this bacteria The algae and zooplankton reservoir could potentially be a source for future cholera epidemics (Colwell, 1996). Changes in surface water quantity and quality are known to increase the incidence of other diarrheal diseases.

Heavy rain events and flooding, as well as drought (with inadequate water supplies and sanitation) are also conducive to outbreaks of water-borne diseases (Epstein, 1999). Outbreaks of Cryptosporidiosis are associated with heavy rainfall in the U.S. (MacKenzie et al., 1994; Rose et al., 2001).

Food and Malnutrition

Climate change puts additional pressure on the world food supply as agricultural productivity is severely affected by floods and droughts. Warmer climates are expected to increase crop yields at higher latitudes and to decrease yields at lower latitudes. Regional differences will greatly affect the climatic impact on agricultural yield, with beneficial effects on production expected only in the developed world. However, the negative effects in the developing world will pose yet another setback for an already impoverished and vulnerable community, increasing the number of malnourished people in these regions (IPCC, 2001b). Human susceptibility to disease may be further complicated by malnutrition. Hunger and malnutrition not only increase infant and child mortality, but cause both physical and intellectual stunting. Studies estimate that climate change will push an additional 40-300 million people into starvation, adding to the estimated 600 million people already considered hungry (Parry and Rosenzweig, 1993).

In addition, climate change is projected to increase the range of crop-consuming herbivores, while the extreme weather associated can precipitate significant outbreaks. Floods foster fungi, while droughts encourage aphids, whiteflies and locust (Rosenzweig et al., 2002).

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Social, Economic and Population Factors

Both severe weather events and gradual warming have the potential to cause social and economic disruption and the displacement of populations. The ability of populations to contend with such events depends upon the social, political and economic conditions within the country (IPCC, 2001b). The potential health impacts associated with such social-economic dislocation and population displacement are unknown at present.

Sea Level Rise

The IPCC (2001a) has projected that sea levels will rise from 10-90cm by the year 2100. Moreover, even if GHG emissions and the climate are stabilized, sea level rise (SLR) will continue on into the 22nd Century (IPCC, 2001a). Since over half the world's population lives within 60km of the sea, rising seas could have devastating effects on coastal populations. Sea level rise can affect food production, water and sanitation and public health (via salinization). Currently 46 million people experience coastal flooding every year. This number is projected to double with SLR, primarily due to increased severity of storm surges.

IX. OIL AND MACROECONOMIC DEVELOPMENT

In 1944, as World War II was ending, world leaders convened in Bretton Woods, NH to create a framework capable of stabilizing the international economy. Three rules were established: 1) free trade of goods, 2) control of capital flows, and 3) fixed currency exchange rates. New institutions were established during this period, including the World Bank, the International Monetary fund, and the United Nations. Soon after, The Marshall Fund boosted former allies in Europe while, in the U.S., the GI Bill subsidized the growth of housing, schools and employment.This group of regulations (sticks), funds (carrots) and institutions helped establish the post WWII world order and propel the global economy.

In 1972, the collapse of rules restraining capital flows allowed greater speculation on currencies.Together with the abandonment of the gold standard, the creation of OPEC and the oil embargo, an exponential rise in oil and gold prices followed. The resulting costs of oil imports for many nations was staggering and required extensive borrowing.This alone began the escalation of debt.And as profits from oil were placed in international banks, these "petrodollars" were loaned to underdeveloped nations for large-scale development projects. By the end of the 1970s,with many of the projects not producing returns, a debt crisis emerged. By 1983, funds flowing out of developing nations to repay the debts exceeded moneys flowing in. Inflation of interest rates and currencies tin the 1980s compounded the debt crisis.

The International Monetary Fund (IMF) responded to the debt crisis by instituting Structural Adjustment Programs (SAPs). SAPs are a set of policy devices designed to increase the Gross National Product (GDP) per capita in debt-burdened countries. The policies involved devaluing domestic currency to improve the competitiveness of exports and discourage imports, creating import substitutions, increasing export products, often at the expense of domestic foods, and increasing government austerity. Government budgets for health, education, housing and other government services were to be cut to reduce expenses. The effects of these policies have been described in detail in development and medical literature. Overall these cuts in government expenditures have weakened state infrastructures. The consequences of inadequate debt management --- in large part propelled by the generation of petrodollars -- have fallen disproportionately upon the poor.

By the early 1990s it became apparent to all -- including policy makers -- that SAPs were widening the income gap between rich and poor while raising the hurdles to the alleviation of poverty (the primary goal of the World Bank). Programs, projects and policies were begun to address the poverty generated, and a modicum of debt-relief has been provided for Heavily-Indebted Poor Countries (HIPC). But there has been little progress in addressing the underlying debt crisis and the unequal terms of trade of commodities that maintain the inequities.

As globalization is changing the terms of international trade, creating new entities for international trade governance such as the World Trade Organization (WTO), many economic policies favoring transnational corporations are being called into question. Protests display a growing concern over the environmental and social equity consequences of globalization and liberalization of trade policy. Most oil companies continue to encourage liberalization of trade in goods and capital. And since much of the world's oil is harvested in developing countries and consumed in developed countries, trade with little regulation poses a continuing threat to social and environmental equity.

OIL AND SECURITY

In the U.S., energy is inextricably linked with the nation's political and economic security. As noted above, fossil fuels account for 85% of the nation's energy expenditures. Two-thirds of the oil used is for the transport sector and two-thirds of the world's oil reserves are in the Middle East. Since energy fuels the U.S. economy, and so much of it is dependent on Middle Eastern supplies,likely disruptions in the future may severely impact the nation's stability and economic growth. The United States currently imports over 50 percent of its oil with nearly a quarter coming from the Persian Gulf. Refineries, transport vessels and power production infrastructure all represent potential targets for terrorist attacks. Long-term energy security, and thus economic security, depends on the provision of adequate, uninterrupted power. Recent policy proposals have suggested increased production in traditional power sources as a means of increasing energy security, providing inadequate support for decreased consumption and the development of alternate sources.

Environmental Justice and the Impacts of Oil

From drilling to refining to air pollution and climate change, the most severe impacts fall disproportionately on poor nations and disadvantaged populations within wealthier nations.

Exploration can introduce infectious diseases that affect isolated, indigenous populations in Ecuador, for example. Emerging diseases associated with land use changes – conversion from forests to farm land -- often strike poor populations first. Poor populations are also vulnerable due to inadequate access to health care.

Localized oil spills and habitat degradation contaminate water supplies, farming lands and fisheries in poor regions of Ecuador and the Niger River Delta.

Refineries in the U.S. are often located near African-American and Native American populations. Cancer-causing chemicals such as benzene primarily affect the health of those living in close proximity to refineries.

Populations living in inner cities often suffer most from concentrated air pollution -- soot and ozone -- due to the proximity with truck and bus routes.

Heat waves often take a disproportionate toll on those living in poor housing without air conditioning and those lacking adequate social supports. The majority of those affected during the 1995 heat wave in Chicago, for example, were African-Americans living in substandard housing.

Extreme weather events -- such as Hurricane Mitch in Honduras (1998), killing over 10,000; severe storms and flooding in Venezuela (1999), killing an estimated 20,000 and leaving 150,000 homeless; and extensive floods in Mozambique (2000 and 2001) – take their greatest toll on poor nations with inadequate resources for recovery (IPCC, 2001b).

X. CONCLUSIONS

Oil provides many benefits to society, and energy is necessary for all out activities. Meanwhile each stage in the life cycle of oil carries hazards for ecosystems, wildlife and humans. Through multiple pathways, the processes of exploration to combustion result in ecological changes, losses to biodiversity, introduction of infectious diseases, air pollution, acid rain and climate change.

In addition, dependence on oil has affected the social fabric within, and the enormous amount of wealth generated is now exerting an overwhelming impact on international relations. We must search for solutions that address oil independence and security, protect the global environment and stimulate the global economy.

Among the proposed solutions include development of new, technologies to improve energy efficiency and generate energy while minimizing pollution. Technologies for carbon sequestration are under investigation.

Fossil fuel use could be significantly decreased if advanced vehicle technologies, such as electric-hybrid and hydrogen-fuel cells, were widely deployed. Distributed generation of renewable energy sources is a way to diversify the nation's energy supply and disburse the locations of energy generation. Renewable energy resources, such as biomass, geothermal, solar, tidal and wind, are abundant and located throughout the United States. Combined heat and power co-generation can also greatly increase the efficiency of a distributed energy network. Efficiency gains and more diffuse and distributed generation could transform the current system into one that is resilient to stresses and deliberate attacks, lowering the nation’s energy bill in the process. In addition, "smart-growth" of urban areas can help minimize transport and optimize activities. Green building technology can complement new urban planning approaches.

This transition will depend on internationally and nationally coordinated policies. Understanding the causes, health consequences and costs of our dependence on oil can lay the foundation for addressing evolving global governance issues A broad perspective will be needed as we attempt to erect the reward and incentive scaffolding structures upon which to build more equitable, sustainable and healthy development in the decades to come. The clean energy transition could prove to be the engine of growth for the global economy in this 21st Century.

APPENDIX

WILDLIFE STATISTICS FOR OIL SPILLS RESPONDED TO BY THE INTERNATIONAL BIRD RESCUE RESEARCH CENTER BERKELEY, CALIFORNIA

This is a list of oil spills involving wildlife that IBRRC has responded to since 1971. Other IBRRC spill responses that did not include oiled wildlife are not listed here. IBRRC's ongoing aquatic bird research/rehabilitation program in Berkeley, California cares for individual oiled wild animals throughout the year. These animals are not listed here, as they are not associated with actual responses. These "mystery" animals average about 50 to 100 a year. Survivability of oiled wildlife varies with each species and each oil spill.There are many variables that can affect the survivability of oiled wildlife. Rehabilitation facilities or lack of them,species affected, weather, location, animal migrations and cooperation from agencies and responsible parties can all effect survivability. The release rates listed below are prime examples of the effect that these variables can have on survivability.

January, 1971 - Standard Oil of California - San Francisco Bay, CA

Birds Treated: 7,000
Mortality: 6,700
Released: 300
Release Rate: 4.5%

January, 1973 - Source Unknown - Oakland Estuary, CA

Birds Treated: 308
Mortality: 165
Released: 143
Release Rate: 46 %

December, 1973 - Source Unknown - San Francisco, CA

Birds Treated: 100
Mortality: 75
Released: 25
Release Rate: 25%

February, 1974 - Source Unknown - San Francisco, CA

Birds Treated: 77
Mortality: 36
Released: 41
Release Rate: 53 %

September, 1975 - Source Unknown - San Mateo Coast, CA

Birds Treated: 635
Mortality: 476
Released: 159
Release Rate: 25%

January, 1976 - Matson Lines - Crockett, CA

Birds Treated: 140
Mortality: 35
Released: 105
Release Rate: 75%

April, 1976 - Colgate - Aquatic Park, Berkeley, CA

Birds Treated: 50
Mortality: 22
Released: 25
Transferred: 3
Release Rate: 56%

February, 1977 - Bethlehem Ship Yard, San Francisco, CA

Birds Treated: 330
Mortality: 288
Released: 42
Release Rate: 13%

December, 1977 - Source Unknown - Martinez, CA

Birds Treated: 44
Mortality: 3
Released: 41
Release Rate: 93%

March, 1978 - Steuart Transportation - Chesapeake Bay, VA

Birds Treated: 400
Mortality: 260
Released: 140
Release Rate: 35%

March, 1978 - Source Unknown - Concord, CA

Birds Treated: 100
Mortality: 29
Released: 66
Transferred: 5
Release Rate: 71%

May, 1979 - Source Unknown - Concord, CA

Birds Treated: 82
Mortality: 14
Released: 68
Release Rate: 83%

May, 1980 - Marathon - Platte River, WY

Birds Treated: 289
Mortality: 198
Released: 91
Release Rate: 32%
Total Mammals Treated: 16
Mortality: 16
Released: 0
Release Rate: 0%
Total Animals Treated: 305

January 4, 2001

Office of Overall Release Rate: 30%

February, 1981 - Source Unknown - Myrtle Beach, SC

Birds Treated: 252
Mortality: 72
Released: 180
Release Rate: 71%

April, 1984 - Mobil - Columbia River, OR

Birds Treated: 458
Mortality: 174
Released: 284
Release Rate: 62%

November, 1984 - Puerto Rican - Marin County, CA

Birds Treated: 624
Mortality: 309
Released: 315
Release Rate: 50%

December, 1985 - ARCO Anchorage - Port Angeles, WA

Birds Treated: 1,562
Mortality: 1,243
Released: 281
Transferred: 38
Release Rate: 18%

February, 1986 - Apex Houston - San Francisco, CA

Birds Treated: 2,512
Mortality: 1,405
Released: 1,107
Release Rate: 44%

April, 1988 - Shell - Martinez Marsh, CA

Birds Treated: 414
Mortality: 117
Released: 297
Release Rate: 72%

September, 1988 - Mobil - Los Angeles River, CA

Birds Treated: 67
Mortality: 23
Released: 41
Release Rate: 61%

December, 1988 through February, 1989 - Gray's Harbor - Nestucca, WA

Birds Treated: 3,058
Mortality: 2,099
Released: 959
Release Rate: 31%

March, 1989 through September, 1989 - Exxon - Alaska

Birds Treated: 1,604
Mortality: 803
Released: 801
Release Rate: 50%

February, 1990 - American Trader - Huntington Beach, CA

Birds Treated: 565 (includes pelicans)
Mortality: 226
Released: 310
Transferred: 29
Overall Release Rate: 60%
Total Pelicans Treated: 141
Mortality: 39

Released: 102
Pelican Release Rate: 78%

February, 1990 - Source Unknown - San Mateo, CA

Birds Treated: 173
Mortality: 111
Released: 53
Transferred: 9
Release Rate: 36%

June, 1990 - Western Transport - San Mateo, CA

Birds Treated: 67
Mortality: 37
Released: 28
Transferred: 2
Release Rate: 52%

December, 1990 - Source Unknown - San Mateo Coast, CA

Birds Treated: 195
Mortality: 154
Released: 41
Release Rate: 21%

January, 1991 - Sammy Superstar - Long Beach, CA

Birds Treated: 56
Mortality: 24
Released: 32
Release Rate: 57%

February, 1991 - Texaco - Anacortes, WA

Birds Treated: 87
Mortality: 49
Released: 38
Release Rate: 44%

February 1991 - Mobil - Santa Clara River, Los Angeles, CA.

Birds Treated: 166
Mortality: 41
Released: 123
Release Rate: 72%
Total Mammals Treated: 3
Mortality: 1
Released: 2
Total Reptiles Treated: 1
Released: 1
Total Fish Treated: 1
Mortality: 1
Total Animals Treated: 171
Overall Release Rate: 75%

May, 1991 - Unocal - Los Angeles, CA

Birds Treated: 6
Mortality: 3
Released: 3
Release Rate: 50%

June, 1991 - Alphius - Long Beach, CA

Birds Treated: 1
Release Rate: 1

July, 1991 - Tenyo Maru - Washington Coast, WA

Birds Treated: 700
Mortality: 550
Released: 150
Release Rate: 21%

October, 1991 - La Esperanza - Long Beach, CA

Birds Treated: 1
Mortality: 1
Released: 0
Release Rate: 0%

September, 1991 - Source Unknown - Punto Tumbo, Argentina

Birds Treated: approximately 400
Expired/Euthanized: unknown (records roughly kept)
Released: approximately 150
Release Rate: data incomplete

November, 1991 - Source Unknown - Crescent City, CA

Birds Treated: 5
Mortality: 3
Released: 2
Release Rate: 40%

December, 1991 - U.S. Navy - San Diego Harbor, CA

Birds Treated: 26
Mortality: 6
Released: 20
Release Rate: 77%

January, 1992 - Chevron - Alcatraz Island, CA

Birds Treated: 3
Mortality: 1

Released: 2
Release Rate: 67%

August, 1992 - Unocal - Avila Beach, San Luis Obispo, CA

Birds Treated: 42
Mortality: 26
Released: 15
Transferred: 1
Release Rate: 38

October, 1992 - Green Hill Petroleum - Timbalier Bay, LA

Birds Treated: 10
Mortality: 0
Released: 10
Release Rate: 100%
Mammals Treated: 1
Mortality: 0
Released: 1
Release Rate: 100%
Total Animals Treated: 11

January, 1993 - Prado Basin - Riverside, CA

Birds Treated: 20
Mortality: 10
Released: 10
Release Rate: 50%
Mammals/Reptiles/Amphibians Treated: 10
Mortality: 0
Released: 10
Release Rate: 100%
Total Animals Treated: 30
Overall Release Rate: 67%

January, 1994 - Bush - Oxnard, CA

Birds Treated: 46
Mortality: 30
Release: 16
Release Rate: 34%

January, 1994 - Four Corners - Valencia, CA

Birds Treated: 32
Mortality: 11
Release: 21
Release Rate: 66%
Mammals Treated: 1
Mortality: 0
Release: 1
Release Rate: 100%
Reptiles Treated: 4
Mortality: 1
Release: 3
Release Rate: 75%
Total Animals Treated: 37
Overall Release Rate: 68%

June, 1994 - Tidelands - Dominguez Channel, Long Beach, CA

Birds Treated: 15
Mortality: 0
Release: 15
Release Rate: 100%

July, 1994 through September, 1994 - Apollo Sea - Cape Town, South Africa

Approximate numbers from Cape Nature Conservation
Birds Treated: 9,672
Mortality: 4,633
Release: 5,003

An additional 86 birds treated at Langebaan and 507 abandoned penguin chicks released.

Release Rate: 51.7%

January, 1995 - McDonell Douglas- Long Beach, CA

Birds Treated: 14
Mortality: 9
Transfer: 1
Reptiles Treated: 1
Mortality: 0
Release: 5
Octopus: 1
Mortality: 0
Release: 1
Release Rate: 36%
Release Rate: 100%
Total Animals Treated: 16
Total Mortality: 9
Total Release/Transfer: 7
Overall Survival Rate: 44%

January, 1995 - Chevron - Venice, LA

Birds Treated: 24
Mortality: 1
Release: 23
Release Rate: 96%

February, 1995 Metrolink - Long Beach, CA
Birds Treated: 96
Data currently unavailable

March 11, 1995 Chevron - Kettleman City, CA
Birds Treated: 23
Mortality: 5
Release: 18
Release Rate: 78%

July 7 through September 1, 1995 BHP - Tasmania, Australia
Birds Treated: 2,124
Mortality: 110
Release: 2014
Release Rate: 95%

September, 1995 - Dyer Spill - Cape Town, South Africa
Birds Treated: Data not yet available
Mortality:
Release:
Release Rate: %

November 28 through December 15, 1995 - Back Bay Spill - Newport Beach, CA
Birds Treated: 9
Mortality: 7
Release: 3
Release Rate: 30%

February 21 through March 31, 1996 - Pribilof Island Spill - Pribilof Islands, AK
Birds Treated: 165
Mortality: 35
Release: 127
Transferred: 3
Release Rate: 77%

March 31, 1996 - Evergreen Oil Spill - Newark, CA
Birds Treated: 2
Mortality: 1
Release: 1
Release Rate: 50%

April 24 & April 25, 1996 - Brea Oil Spill - Brea, CA
Birds Treated: 8
Release: 8
Release Rate: 100%

July 29 through August 11, 1996 - Cerritos Channel Spill - Long Beach, CA
Birds Treated: 35
Mortality: 9
Release: 26
Release Rate: 74%

October 29 through November 17, 1996 - Cape Mohican Spill - San Francisco, CA
Birds Treated: 58
Mortality: 22
Release: 36
Release Rate: 63%

November 20 through December 31, 1997 - Cordigliera Spill - Port Elizebeth, South Africa
Birds Treated: 1,200
Mortality:
Release:
Release Rate: Date not yet available

January 9, through February 1, 1997 - Bollona Creek Spill - Long Beach, CA
Birds Treated: 160
Mortality: 50
Release: 100
Release Rate: 63%

January through February 19, 1997 - Nakhodka oil Spill, Japan
Birds Treated: 136
Mortality: 49
Release: 87
Release Rate: 58%

July 17 & 18, 1997 - Penitencia Creek Spill - Milpitas, CA
Birds Treated: 7
Mortality: 1
Release: 6
Release Rate: 86%

September 29 through October 23, 1997 - Torch Oil Spill - Lompoc, CA
Birds Treated: 53
Mortality: 33
Release: 18

Transferred: 2
Release Rate: 34%

October 25 through November, 1997 - Fish/Vegetable Oil Spill - Santa Cruz, CA
Birds Treated: 505
Mortality: 250
Release: 255
Release Rate: 50%

November 5 through November, 1997 - Humboldt Bay Oil Spill - Eureka, CA
Birds Treated: 484
Mortality: 177
Release: 195
Release Rate: 40%

November 16 through December 25, 1997 - Pt. Reyes Mystery Oil Spill # I, Pt. Reyes, CA
Birds Treated: 303
Mortality: 196
Release: 79
Release Rate: 27%

January 11 through January 20, 1998 - Carson, CA
Birds Treated: 153
Mortality: 6
Release: 147
Release Rate: 96%

December 26 through March, 1998 - Pt. Reyes Mystery Oil Spill # II, Pt. Reyes, CA
Birds Treated: 635
Mortality: 345
Release: 290
Release Rate: 46%

February 26 through March 8, 1989 - Santa Barbara Mystery Spill, Santa Barbara, CA
Birds Treated: 39
Mortality: 28
Release: 6
Release Rate: 23%

June 25, 1998 - Vaya Con Dios Spill, Pacifica, CA
Birds Treated: 1
Mortality: 1
Release: 0
Release Rate: 0%

July, 1998 Lake Union Spill - Seattle, WA
Birds Treated: 5
Mortality: 1
Release: 4
Release Rate: 80%

September 28 through November 6, 1998 - Command Spill, San Mateo Coastline, CA
Birds Treated: 76
Mortality: 46
Transferred: 1
Release: 29
Release Rate: 38 %

September 8 through October 24, 1998 - HMS Hose Spill - Kauai, HI
Birds Treated: 33
Mortality: 14
Transferred: 0
Release: 19
Release Rate: 55%

November 1998 - Pallas Spill, Fohr & Amrum Island, Germany
Data not yet available

December 14 through 30, 1998 - Winterburg Channel Spill, Huntington Beach, CA
Birds Treated: 50
Mortality: 24
Transferred: 0
Release: 28
Release Rate: 56 %

December 15 through 22, 1998 - El Segundo Refinery, El Segundo, CA
Birds Treated: 23
Mortality: 7
Transferred: 0
Release: 16
Release Rate: 70%

January 7 through January 20, 1999 - Delphi Heating Oil Spill, Astoria, OR
Birds Treated: 12
Mortality: 11
Transferred: 0
Release: 1
Release Rate: 8%

January 22 through February, 5 1999 - College Park Spill - Huntington Beach, CA

Birds Treated: 15
Mortality: 3
Transferred: 0
Release: 12
Release Rate: 80%

January 25 through February 9, 1999 - Golden West Spill, Huntington Beach, CA

Birds Treated: 35
Mortality: 14
Transferred: 0
Release: 21
Release Rate: 60%

Feb 8 through March 29, 1999 - New Carissa Oil Spill, Coos Bay & Waldport, OR

Birds Treated: 175
Mortality: 43
Transferred: 0
Release: 129
Release Rate: 74%

June, 1999 - Calloway Canal Spill, Bakersfield, CA

Birds Treated: 25
Mortality: 8
Transferred: 0
Release: 17
Release Rate: 68 %

July, 1999 - Davis Golf Course Motor Oil Spill, Davis, CA

Birds Treated: 11
Mortality: 0
Transferred: 0
Release: 11
Release Rate: 100 %

September 1999 - Stuyvesant Oil Spill, Eureka, CA

Birds Treated: 644
Mortality: 354
Transferred: 0
Release: 288
Release Rate: %

October 12 through 14, 1999 - Bollona Creek, Los Angeles, CA

Birds Treated: 5
Mortality: 0
Transferred: 0
Release: 5
Release Rate: 100 %

October, 1999 Stockdale/Oildale Oil Spill - Bakerfield, CA

Birds Treated: 21
Mortality: 16
Transferred: 0
Release: 5
Release Rate: %

November 25 through Dec. 4 - 1999 Four Bayou Spill, Grande Isle, LA

Birds Treated: 15
Mortality: 0
Transferred: 0
Release: 15
Release Rate: 100%

January 3 through January 31, 2000 - Erika Oil Spill - Brittany, France

Current numbers as of 5/22/2000
Birds live and dead picked up: 63,573
Mortality: 61,628
Release: 1,945

February, 2000 - Canola Oil Spill - Vancouver, British Columbia, Canada

Data not yet available

March, 2000 - Malibu Mystery Spill - Malibu, CA

Mortality: 2
Transferred: 0
Release: 1
Release Rate: 33%

March, 1, 2000 -Berkeley Mystery Spill, Berkeley, CA

Birds Treated: 2
Mortality: 2
Transferred: 0
Release: 0
Release Rate: 0%

March, 2000 - Hunter's Point Spill- San Francisco, CA

Birds Treated: 1
Mortality: 1
Transferred: 0
Release: 0
Release Rate: 0%

June, 2000 - Trona Spill #1, Trona, CA

Birds Treated: 18
Mortality: 11
Release: 7
Release Rate: 39 %

September, 2000 - Trona Spill #2, Trona, CA

Birds Treated: 11
Mortality: 6
Release: 5
Release Rate: 45 %

June through September, 2000 - Treasure Spill - Cape Town, South Africa

Birds Treated: 20,251
Mortality: 1,957
Release: 18,200
Release Rate: 90 %

November, 2000 - Arco Refinery Spill - Los Angeles, CA

Birds Treated: 3
Mortality: 3
Release: 0
Release Rate: 0%

January, 2001 - Equalon - Long Beach, CA

Birds Treated: 12
Mortality: 1
Release: 11
Release Rate: 0%

Note: Oil spills where IBRRC was not the lead organization but assisted other organizations or state and federal agencies in the management of the rehabilitation program.

Updated 11/ 10 / 2000

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