SKM 4353 Safety in Petroleum Engineering Chapter 7: Environmental Sustainability

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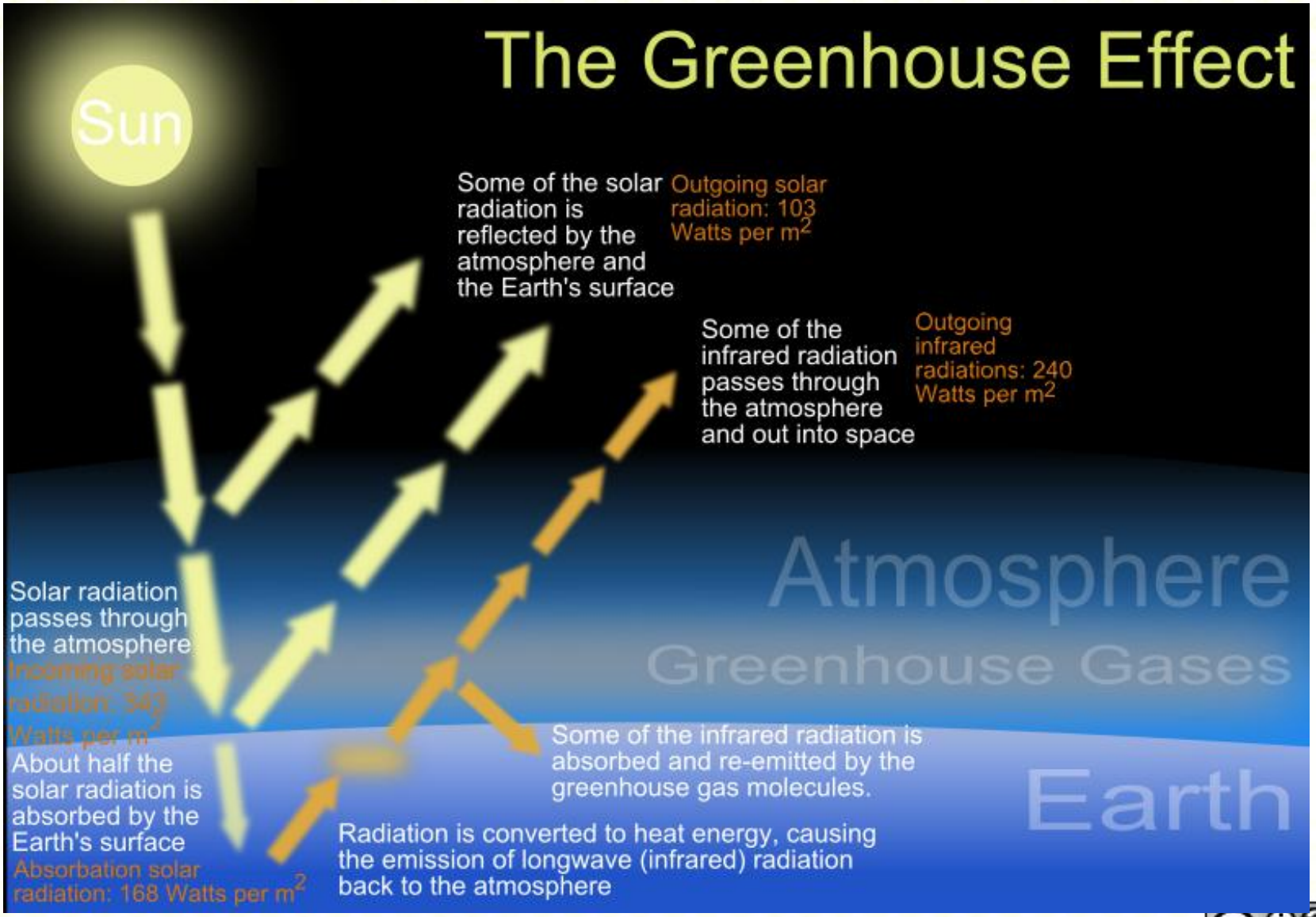
Environmental issues

- Global warming - Green house gasses
- Air pollution
- Water pollution - Produced water
- Drilling mud and drill cuttings disposal
- Oil spills
- Solid disposal
- Wastewater in petrochemical industry

Environmental sustainability

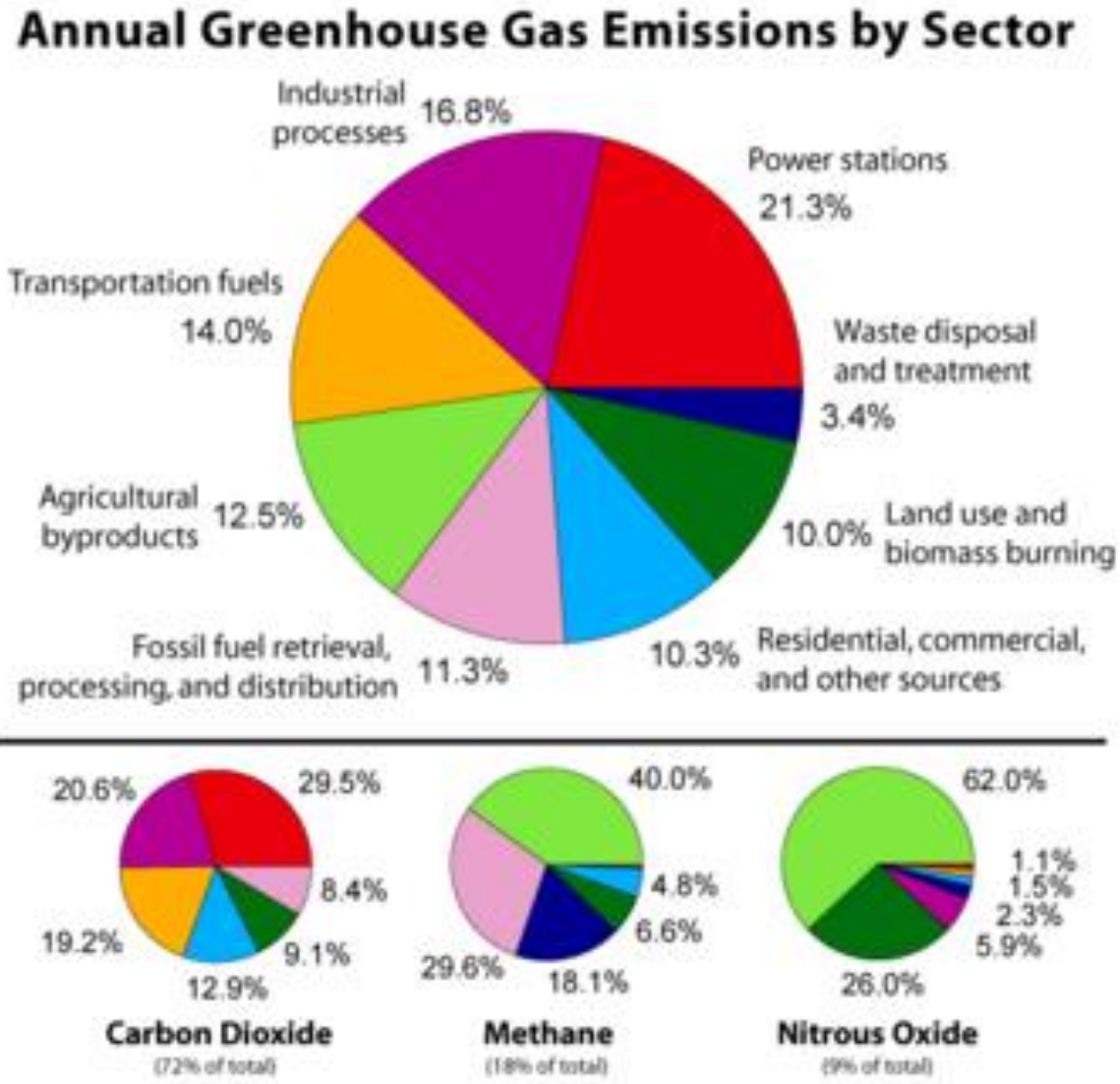
GREEN HOUSE GASSES


The Greenhouse Effect
Sun
Some of the solar radiation is reflected by the atmosphere and the Earth's surface
Outgoing solar radiation: 103 Watts per m2
Some of the infrared radiation passes through the atmosphere and out into space
Outgoing infrared radiations: 240 Watts per m2
Atmosphere
Greenhouse Gases
Solar radiation passes through the atmosphere
Incoming solar radiation: 343 Watts per m2
About half the solar radiation is absorbed by the Earth's surface
Absorbation solar radiation: 168 Watts per m2
Some of the infrared radiation is absorbed and re-emitted by the greenhouse gas molecules.
Radiation is converted to heat energy, causing the emission of longwave (infrared) radiation back to the atmosphere
Earth

Green house gasses

- **Greenhouse gases** are gases in an atmosphere that absorb and emit radiation within the thermal infrared range
- This process is the fundamental cause of the greenhouse effect
- The main greenhouse gases in the Earth's atmosphere are water vapor, carbon dioxide, methane, nitrous oxide, and ozone
- The burning of fossil fuels since the Industrial revolution has increased the levels of greenhouse gases in the atmosphere.

CO_2 and methane

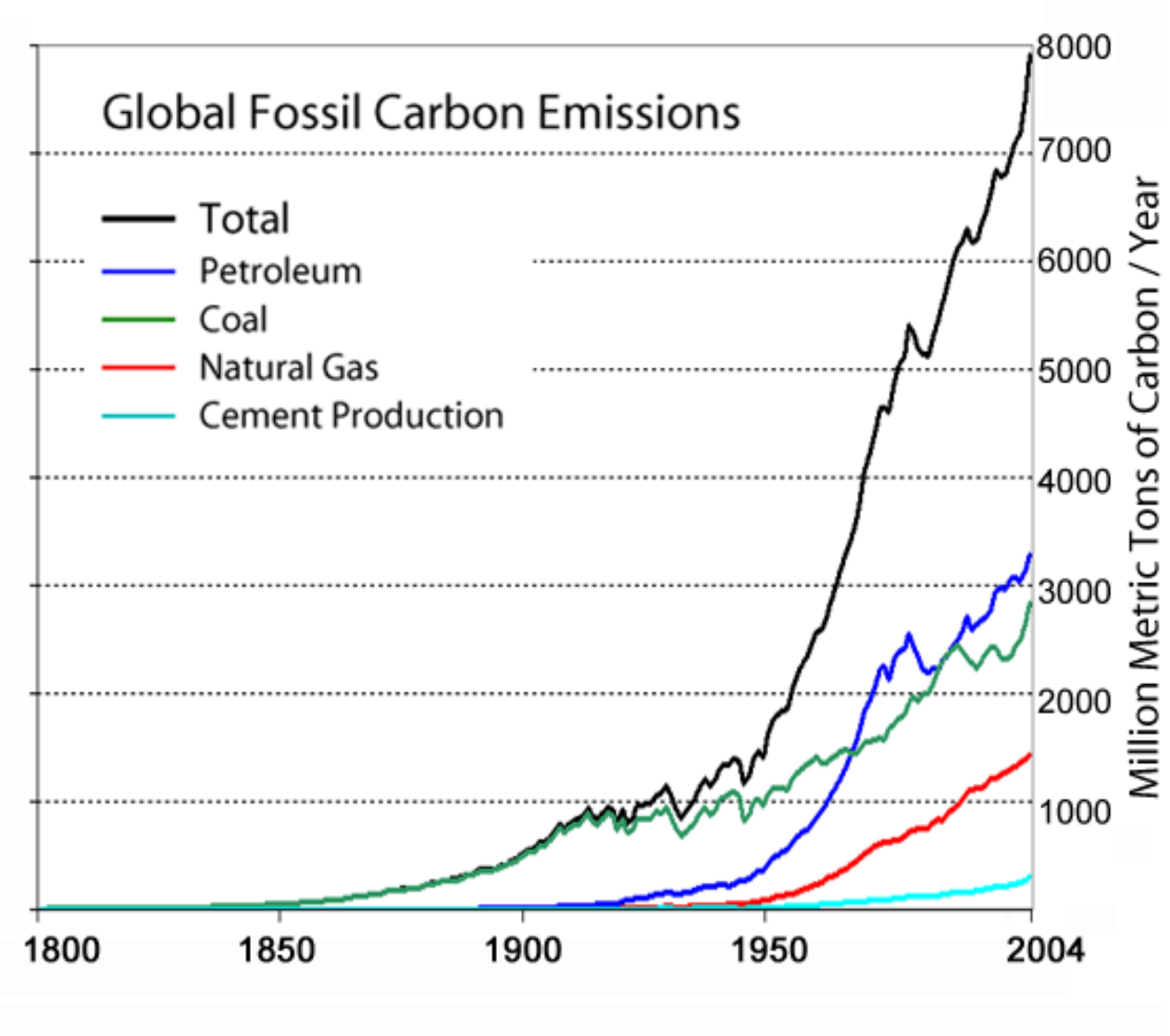


CO_2 sources

The seven sources of CO_2 from fossil fuel combustion are (with percentage contributions for 2000–2004):

- Solid fuels (e.g., coal): 35%
- Liquid fuels (e.g., gasoline, fuel oil): 36%
- Gaseous fuels (e.g., natural gas): 20%
- Flaring gas industrially and at wells: <1%
- Cement production: 3%
- Non-fuel hydrocarbons: < 1%
- The "international bunkers" of shipping and air transport not included in national inventories: 4%

Carbon dioxide



Environmental sustainability

PRODUCED WATER

Produced water

- In USA: 20 billion bbl/yr.
- Detrimental effects on soils, surface and groundwater and also the ecosystems.
- Abandoned well which are not correctly plugged.
- Related activities – site clearance, construction of roads, brine pits, pipelines

Produced water - hazard

- Highly saline (3000-350,000 mg/L total dissolved solid).
- May contain toxic metals, organic and inorganic components.
- May contain radium-226/228 and other naturally occurring radioactive materials
- Contaminated by traces of hydrocarbons.

Produced water handling

- Prior to 1970 : discharged into streams, creeks and unlined ponds – surface and groundwater pollution.
- Become an issue to producers, land owners, state and federal regulators.
- More recently, new environmental laws and improved industry practices and technology have reduced the problem.

Other causes of release

- Leaks – pipelines, tanks, wellheads, pits.
- Overflow – tank, pit, dike.
- Intentional dumping/illegal activities
- Storms
- Fire/explosion
- corrosion

Examples of remediation methods

- Use of hay and fertilizer in contaminated sites.
- Subsurface drainage system to intercept brine from a pipe leak.
- Smart well – proactively control flow of water from formation into producing wells.

Environmental sustainability

AIR POLLUTION

Air contaminants

- Benzene, Toluene, Ethylbenzene and Xylene (BTEX)
- Carbon Monoxide
- Dust
- Hydrogen Sulfide
- Nitrogen Oxides
- Ozone
- Particulate Matter
- Sulfur Dioxide
- Volatile Organic Compounds

BTEX compounds

- Benzene is a known carcinogen, and has also been shown to cause blood disorders and to impact the central nervous system the reproductive system.
- Toluene may affect the reproductive and central nervous systems.
- Ethylbenzene and xylene may have respiratory and neurological effects.
- BTEX compounds can be emitted during various oil and gas operations activities, including flaring, venting, engines, produced water storage tanks, and during the dehydration of natural gas.

Carbon monoxide

- Carbon monoxide is emitted during flaring and from the operation of various machinery at oil and gas development sites.
- It is a colorless, odorless, flammable gas produced by incomplete burning of carbon-based fuels such as oil, natural gas, coal, and even wood.
- Carbon monoxide is poisonous if inhaled. It inhibits the blood's ability to carry oxygen, and can cause dizziness, unconsciousness, and even death.

Nitrogen Oxides

- NOx are formed during the combustion of fossil fuels, which causes a chemical reaction between nitrogen (which occurs naturally in the atmosphere) and oxygen.
- During oil and gas production, NOx are formed during flaring operations, and when fuel is burned to provide power to machinery such as compressor engines and other heavy equipment.
- Nox may react with VOCs to form ground-level ozone.
- Nitrogen dioxide, one of the NOx chemicals, is a criteria pollutant regulated by the EPA, and can be seen, along with other particles in polluted air, as a reddish-brown haze. The health impacts from NOx include respiratory problems, heart conditions, and lung damage,

Ozone

- Ozone itself is not released during oil and gas development. But some of the main compounds that combine to form ozone (e.g., volatile organic compounds and nitrogen oxides) are released from oil and gas operations.
- Ozone, when found at ground-level, is also referred to as "smog," which, when inhaled can cause or aggravate respiratory ailments such as asthma.

Particulate matter

- composed of small particles that are suspended in the air and settle to the ground slowly.
- The most common sources of particulate matter from oil and gas operations are dust or soil entering the air during pad construction, traffic on access roads, and diesel exhaust from vehicles and engines used to power machinery at oil and gas facilities.
- Particulate matter can also be emitted during venting and flaring operations. The inhalation of these particles may lead to adverse health effects such as respiratory or breathing ailments, cancer, or premature death.
- Particulate matter suspended in air may also contribute to decreased visibility (i.e., regional haze).

Sulfur dioxide

- Sulfur dioxide is formed when fossil fuels containing sulfur are burned.
- Many oil, natural gas, and coal formations contain traces of sulfur. Thus, SO2 may be emitted during flaring of natural gas, or when fossil fuels are burned to provide power to pump jack or compressor engines or other equipment and vehicles at oil and gas sites.
- Sour gas processing plants also emit sulfur dioxide. SO2 is regulated by the EPA as a criteria air pollutant, and along with NOx, is a principal contributor to acid rain.
- Sulfur dioxide reacts with other chemicals to form particulate pollution, which can damage lungs and cause respiratory illness, heart conditions, and premature death.

Source of Oil & Gas air pollution

- Blowouts
- Condensate tanks
- Construction activity
- Dehydrators
- Engines
- Flaring
- Fugitive emissions
- Pits
- Vehicles Venting

Environmental Sustainability

ENVIRONMENTAL CHALLENGES IN PETROLEUM INDUSTRY

Uniqueness of Petroleum Industry

- Largest money earning industry
- Diverse in products and pollutants
- To an extent, similar to coal industry

Environmental Challenges from Source to End Use

- Drilling, processing and transportation
- Crude refining and transportation
- Use as fuel in industry and motor vehicles
- Downstream processing for petrochemicals

Oil Drilling & Production

Pollution in Drilling & Production

- Exhaust gases from diesel engines and power generation sets
- Products of combustion due to flaring (low pressure, high pressure or technical flare)
- Produced water containing dissolved and emulsified crude oil constituents, natural salts, organic chemicals and trace metals
- Solid wastes comprising drill cuttings and drilling fluid mud
- Oil spills
- Noise

Problems in Drilling Operations

- Disposal of drill cuttings(800-1200tonnes/well)
- Disposal of unusable drilling fluids(500-700 tonnes /well)
- Disposal of treated water (formation water)
- Flaring of gases (400-1500Nm^3/hr)

Standards & Guidelines for Drilling (1996)

- Drill cuttings to be transported through a conveyor system to the disposal pit after proper washing
- No drill cuttings (of any composition) shall be disposed off shore
- Disposal of drill cuttings (on shore /off shore) shall conform to the MOEF guidelines

Standards & Guidelines for Drilling (1996)

- Drilling mud to be disposed in secured landfill
- For off shore installation , unusable portion of the drilling mud shall be brought back to the shore for disposal in secured landfill
- The spent oil based mud shall be brought back to shore for proper treatment or incineration

Revised Guidelines for Disposal of Drill Cuttings and Drilling Fluids: On-Shore Installations

- Drill cuttings originating from on-shore or locations close to the shoreline and separated from Water Base Mud(WBM) should be properly washed and unusable drilling fluids such as WBM, Oil Base Mud(OBM) should be disposed in a well designed pit with impervious liner and leachate collection system
- OBM having <1.0% aromatic content is permitted in special cases

Revised Guidelines for Disposal of Drill Cuttings and Drilling Fluids: On-Shore Installations

- Drill cuttings after washing should have oil content less than 1mg/kg
- Barite used for drilling fluid should not contain mercury more than 1mg/kg and cadmium more than 3mg/kg
- Drill site should be restored after completion of drilling operations and waste material should be removed
- Environmentally acceptable methods for disposal of drill waste such as injection to formation through casing annulus,land farming, bio-remediation, incineration and solidification may be permitted on a case to case basis.

Revised Guidelines for Disposal of Drill Cuttings and Drilling Fluids: Off-Shore Installations

- Use of diesel base mud is prohibited. Only WBM is permitted for off-shore drilling except in special cases where OBM with low toxicity may be permitted
- The chemical additives used in drilling fluid should be bio-degradable and with low toxicity
- Hexavalent chromium compound should not be used in drilling fluid and in case chromium compound is used, the DF?DC should not be disposed off-shore

Revised Guidelines for Disposal of Drill Cuttings and Drilling Fluids: Off-Shore Installations

- Bulk discharge of drilling fluid should be avoided
- WBM/OBM/SBM should be recycled to the maximum extent. Unusable portion of WBM should not be discharged into sea
- Drill cuttings of any composition should not be discharged in sensitive areas notified by MOEF

Revised Guidelines for Disposal of Drill Cuttings and Drilling Fluids: Off-Shore Installations

- Where drill cuttings are associated with high oil content from hydrocarbon bearing formation , the drill cuttings with oil content more than 10mg/kg should not be disposed off-shore
- DC water should be treated to conform to the standards before disposal into sea
- Daily discharge of DC and DF should be monitored

Oil Refining

Minimizing Emissions

- For minimizing emissions of sulphur dioxide, use of fuel with lower sulphur content, upgradation of SRU unit and tail gas treatment
- Retrofitting of Nox burners in existing refineries and low Nox burners in new units
- Use of Leak Detection & Repair (LDAR), vapour recovery system and switch over to refrigeration system for LPG storage to reduce hydrocarbon loss and VOC emissions
- Compliance of fuel quality standards

Minimizing Wastewater

- Reuse and recycling of treated effluent(e.g waste water use in de-salter and fire fighting system)
- Compliance of progressively stringent effluent standards
- Move towards 100% utilisation of waste water and zero discharge

Solid Waste Management

- New technologies for improving recovery of oil from oily waste
- Improvement in handling and disposal of oily sludge (Oil zapper)
- State of art technologies for preventing oil spillage at crude loading/unloading facilities
- Reuse of petroleum coke with high sulphur content by large scale industries with proper pollution control systems

Environmental Sustainability

OIL SPILLS

Damaging Effects of Oil Spills

- Oil on the water's surface can catch on fire and pollute the air.
- Oil can sink to the ocean floor and destroy the habitats of sea animals.
- Oil can react with oxygen in the air to form acids that are carried by wind and eventually fall back to the ground as acid rain.
- Oil washes up on beaches and marshes resulting in life threatening habitats for wildlife species.
- Sea turtles, birds, whales, fish, otters and other animals can become oil-soaked and die.
- Dear, bears, wolves, dogs, and cats can die from eating oil-soaked beach plants and animal carcasses.

How can oil spills be cleaned up?

- Contain spill with oil booms. Booms are giant styrofoam logs wrapped in plastic that act like a floating fence.
- Vacuum up spilled oil with skimmer boats. A skimmer is a boat with special equipment that collects oil from the surface of calm waters.
- Absorb the oil with sawdust, straw, foam chips, or other sorbents.
- Use chemicals to disperse the oil into small droplets and let it drift out to sea.
- Biodegrade the oil by spreading microbes on beaches. Microbes are tiny organisms that can digest the oil.

How can oil tanker spills be prevented?

Design safer oil tankers.

- Double lined bottom instead of single metal layer.
- Separate compartments for oil storage. In a double-hull tanker, the cargo tanks are separated from the ships outer hull to protect against the impact of an accident.

Thorough training of tanker crews.

- Develop better emergency procedures.
- Improve navigation skills.

Petrochemical Industry

Waste Water

- Cooling water blow down
- Storm water
- Process effluents
- Leakage, drainage and unforeseen discharges from process equipment
- Combination of treatment methods to remove oil and other contaminants before discharge.Plant wise treatment inside battery limit (ISBL)and combined treatment outside battery limit(OSBL)

Wastewater Treatment Plant

Emissions

- Emissions of VOC's/ organic HAP's from process vents, storage vessels, transfer tanks, equipment and fittings (fugitive emissions)
- Combustiondevices(Incinerators/flares/heaters), recovery/recapture devices (adsorption, condensation etc) and specific techniques for transfer racks

Solid Wastes

- Petrochemical plants generate solid wastes and sludge some which are hazardous in nature due to toxic organics and heavy metals (e.g. spent caustic)
- Proper facilities should be provided for handling and storage of hazardous wastes. For final disposal , recycling/reuse should be given priority. For incinerable wastes, properly designed incinerators should be installed and non-incinerable hazardous wastes should be disposed in secured landfill (TSDF)

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