GE 302 - Industry and the Environment

Chapter I

Introduction to Environment, Ecosystems, Environmental Components, Natural Cycles, and Development

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Chapter I – Introduction to Environment, Ecosystems, Environmental Components, Natural Cycles, and Development

(review Chapter 5 of the textbook for more information)

Environment:
It is all the conditions, circumstances, and influences surrounding, and affecting the development of an organism or group of organisms within the space they live in. This includes natural features; for example, mountains, trees, seas and oceans, air, water, energy, land, etc. and how the organism or groups of organisms interact with such features. *In summary, it is the sum of all external conditions affecting the life, development and survival of an organism.*

Environmental Components of the Earth:

1- Atmosphere: it is the gaseous envelope of air surrounding the earth to a height of approximately 1,000 km and mainly consists of 21% oxygen, 78% nitrogen, and 1% other gases, and rotates with the earth, because of gravity.
2- Hydrosphere: all the water on the surface of the earth, including oceans, seas, lakes, glaciers, etc. Water vapor, clouds, etc. may be considered part of the atmosphere or the hydrosphere.
3- Pedosphere: is the outermost layer of the earth that is composed of soil and subject to soil formation processes.
4- Biosphere: It is the portion of Earth and its atmosphere that can support life.

Ecology: is the science that deals with the relationship of living things to one another and their environment, or the study of such relationships.

Groups of interacting populations at a particular location comprise what is known as a community. Examples: consider the plant community of a tropical rainforest, the fish community of a freshwater lake, or the bird community of a saltwater marsh. Communities have many characteristics that are of interest to ecologists. One of the most important of these is the number of species present in a community or the species diversity of the community.

Biodiversity: Refers to the variety and variability among living organisms and the ecological complexes in which they occur. Diversity can be defined as the number of different items and their relative frequencies. For biological diversity, these items are organized at many levels, ranging from complete ecosystems to the biochemical structures that are the molecular basis of heredity. Thus, the term encompasses different ecosystems, species, and genes.

Ecosystem

It is the interacting system of a biological community and its non-living environmental surroundings.In a given area, all populations (the community) and the physical environment comprise an ecosystem -- note that the ecosystem has both biotic and abiotic components.

Biotic components are the living things that shape an ecosystem. They are, in entirety, any living component that affects another organism. Such things include animals which consume the organism in question, and the living food that the organism consumes. As opposed to **Abiotic components** (non-living components of an organism's environment, such as temperature, light, moisture, air currents, etc.), biotic components are the living components of an organism's environment, such as predators and prey.

Ecosystems are structured to be viewed as a series of biotic components that are linked together and thus interact with one another. The fact that ecosystem components are linked has an important ramification: disturbances to one component impact on all other components of the ecosystem to varying degrees.

The interactions between ecosystem components involve two general processes:

1. Energy flow.

2. Nutrient cycling.

Ecosystems are structured according to how different populations acquire energy, species obtaining energy in a similar way are grouped into trophic levels which are three primary trophic levels:

a. Primary producers b. Consumers c. Decomposers

1. Energy Flow

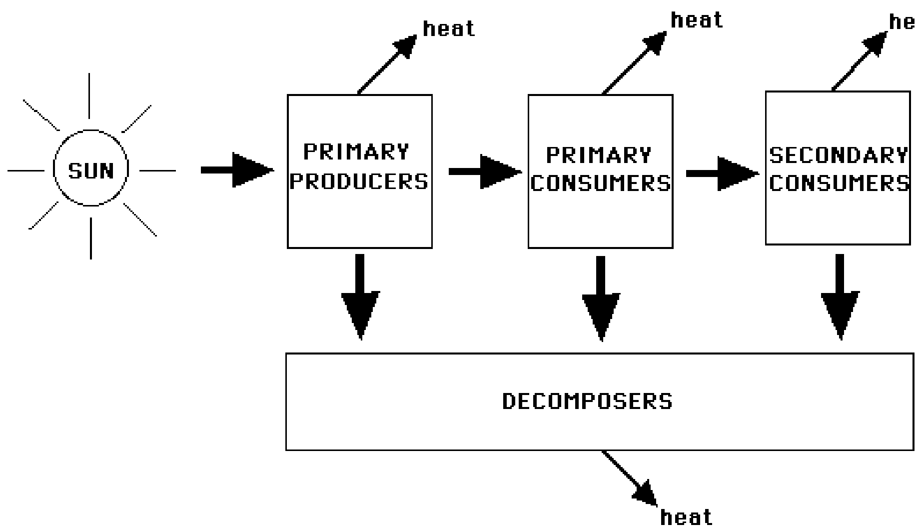
It is a one-way process in ecosystems, in order to persist, ecosystems require a constant input of energy.

1. The sun is the ultimate source of energy for most ecosystems.

2. Primary producers capture a fraction of energy in sunlight striking the earth and convert it into chemical energy (carbohydrate) that is stored in tissues of the primary.

3. Energy in tissues of primary producers transferred to consumers as each consumes tissue of other organisms -- about 90% - 95% of energy present in one component is lost as heat at each transfer -- very inefficient process -- very little energy left when decomposers get to it.

4. Important point is that energy does not cycle through ecosystems -- ecosystems require constant energy input from sun or some other source.



2. Nutrient Transfer

a) Producers: autotrophic organisms capable of photosynthesis, they make food for themselves and indirectly for other components; these are primarily green plants. Plants convert inorganic substances; for example: Carbon dioxide CO_2, water and minerals into simple organic substances (carbohydrates and proteins) using solar energy; hence the plants grow in size.

$$CO_2 + H_2O \xrightarrow{\text{(light + chlorophyll)}} O_2 + \text{organic substance (Biomass)}$$

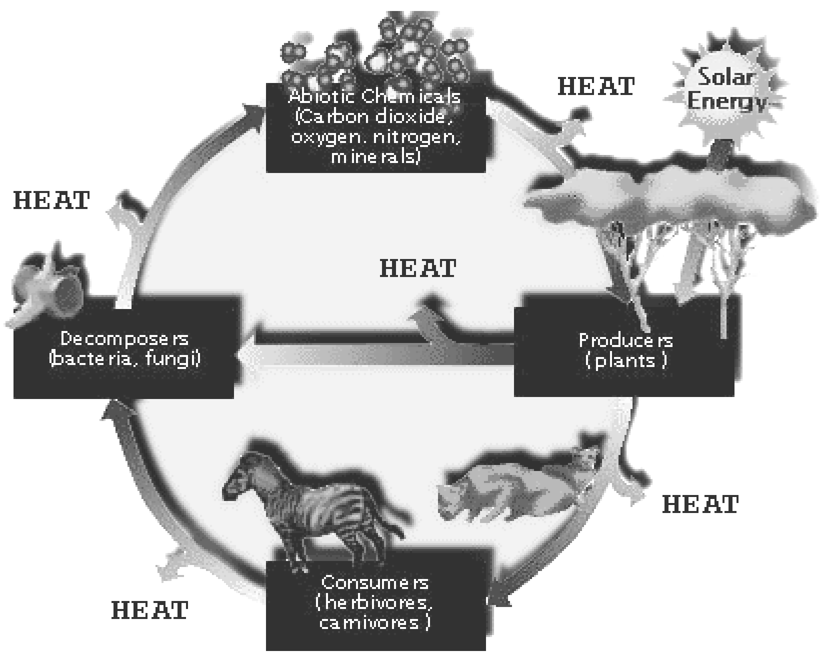
Biomass: All of the living material in a given area; often refers to vegetation.

b) Consumers: heterotrophic organisms dependent on other organisms for food, consumers can be subdivided into more specific trophic levels --those feeding directly on producers are called primary consumers (herbivores), secondary and tertiary consumers (carnivores) eat other consumers.

c) Decomposers: are organisms that obtain energy and nutrients from remains of dead producers and consumers; they are primarily bacteria and fungi and they are extremely important to the process of nutrient cycling (see natural cycles of phosphorous, nitrogen and carbon). Decomposers convert the organic substances into inorganic substances. Decomposers are classified according to their oxygen demand into: aerobic (needs oxygen to function), anaerobic (function in the absence of oxygen) and facultative (function in presence and absence of oxygen).

Biodegradable: Capable of decomposing under natural conditions.

Life Cycle and Energy & Nutrient Transfers

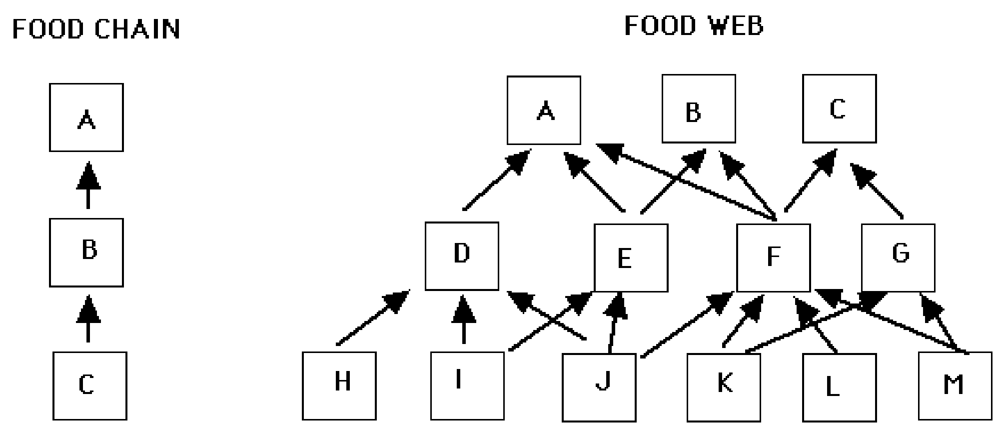


The Life Cycle of Our Earth Ecosystem

The rate at which primary producers remove carbon from the atmosphere and convert it into biomass (living tissue) is called the primary productivity of the ecosystem -- productivity varies greatly from ecosystem to ecosystem -- here are some representative values:

Ecosystem	g C/ m^2 /year
tropical rainforest	2200
Grassland	600
Deserts	90
coral reefs	2500
lakes and streams	250
open ocean	125

Trophic relationships -- we can sometimes describe "who-eats-whom" in an ecosystem as a food chain -- more often, however, food chains are "cross-linked" into more complicated structures called food webs.



Notice that as the ecosystem diversity (e.g. number of species) increases, the complexity of these food webs also increases -- as complexity increases so does stability -- e.g. disturbance or extinction of one or two species can be compensated for -- in simple food webs or chains, extinction of one species may lead to the collapse of the entire system. Examples: Eskimos living mainly on fish and hunting of few polar animals are less stable than humans living around the equator living on more diverse ecosystems.

Natural Cycles of Major Elements in Our Ecosystem

1- Water (Hydrological Cycle)

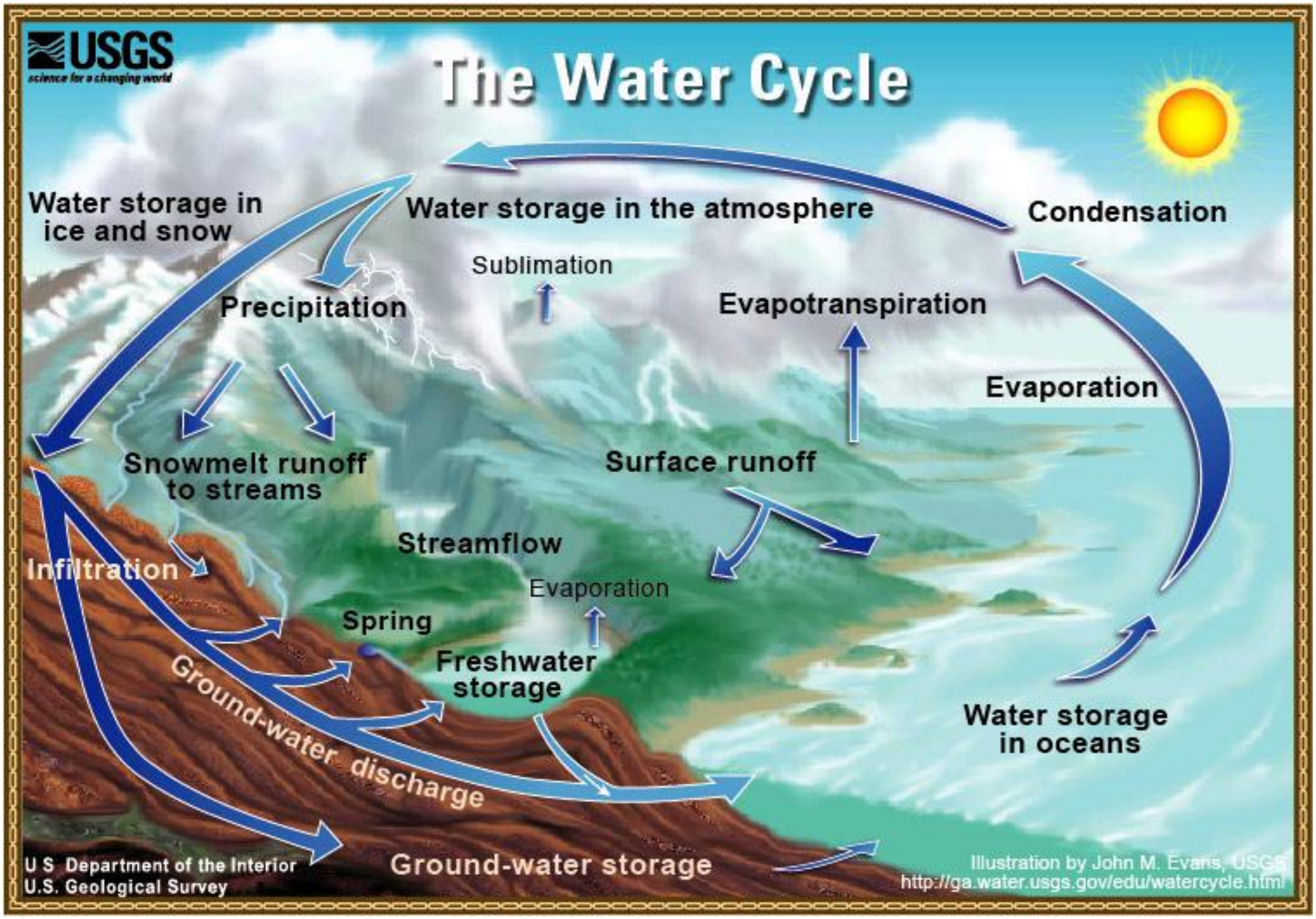
(see the figure on next page; source US Geological Survey (USGS) webpage)

(Review Section 7-1 in Chapter 7 of the textbook)

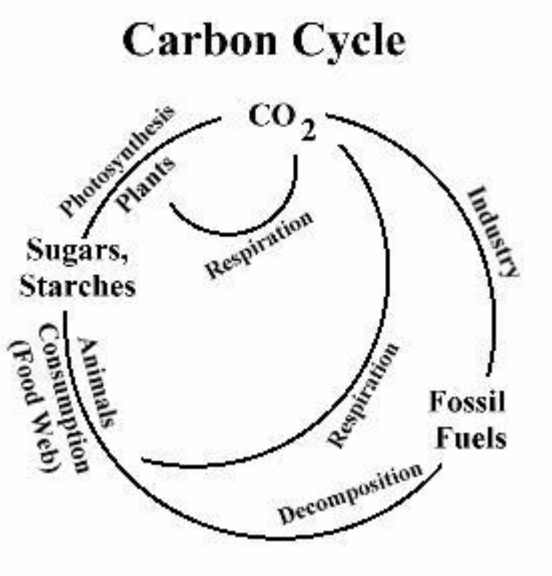
The water cycle describes the existence and movement of water on, in, and above the Earth. The water cycle has been working for billions of years and all life on Earth depends on it continuing to work.

The water cycle has no starting point. But, we'll begin in the oceans, since that is where most of Earth's water exists. The sun, which drives the water cycle, heats water in the oceans. Some of it evaporates as vapor into the air. Ice and snow can sublimate directly into water vapor. Rising air currents take the vapor up into the atmosphere, along with water from evapotranspiration, which is water transpired from plants and evaporated from the soil. The vapor rises into the air where cooler temperatures cause it to condense into clouds. Air currents move clouds around the globe, cloud particles collide, grow, and fall out of the sky as precipitation. Some precipitation falls as snow and can accumulate as ice caps and glaciers, which can store frozen water for thousands of years. Snowpacks in warmer climates often thaw and melt when spring arrives, and the melted water flows overland as snowmelt.

Most precipitation falls back into the oceans or onto land, where, due to gravity, the precipitation flows over the ground as surface runoff. A portion of runoff enters rivers in valleys in the landscape, with streamflow moving water towards the oceans. Runoff, and ground-water seepage, accumulate and are stored as freshwater in lakes. Not all runoff flows into rivers, though. Much of it soaks into the ground as infiltration. Some water infiltrates deep into the ground and replenishes aquifers (saturated subsurface rock), which store huge amounts of freshwater for long periods of time. Some infiltration stays close to the land surface and can seep back into surface-water bodies (and the ocean) as ground-water discharge, and some ground water finds openings in the land surface and emerges as freshwater springs. Over time, though, all of this water keeps moving, some to reenter the ocean, where the water cycle "ends" or "begins" again.


USGS
science for a changing world
The Water Cycle
Water storage in ice and snow
Water storage in the atmosphere
Condensation
Sublimation
Precipitation
Evapotranspiration
Evaporation
Snowmelt runoff to streams
Surface runoff
Streamflow
Infiltration
Evaporation
Spring
Freshwater storage
Ground-water discharge
Water storage in oceans
Ground-water storage
U S Department of the Interior
U.S. Geological Survey
Illustration by John M. Evans, USGS
http://ga.water.usgs.gov/edu/watercycle.html

2- Carbon Cycle (C-Cycle) (For this and the following cycles, review Section 5-4 in Chapter 5 of the textbook for more details)



Organic chemicals are made from carbon more than any other atom, so the Carbon Cycle is a very important one. Carbon between the biological to the physical environment as it moves through the carbon cycle.

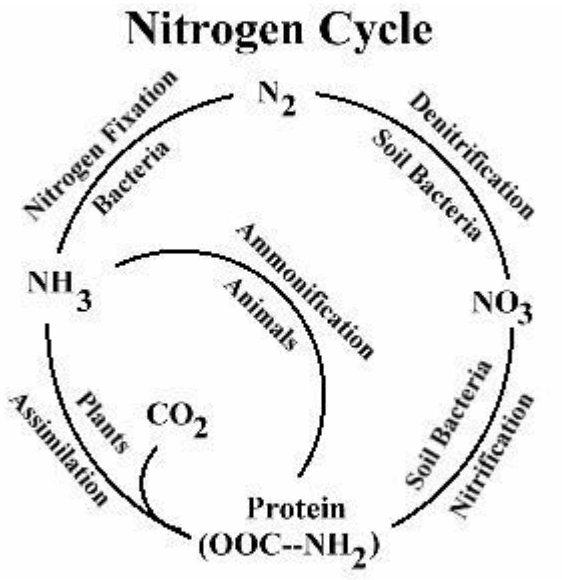
Earth's atmosphere contains 0.035% carbon dioxide, CO_2, and the biological environment depends upon plants to pull carbon into sugars, proteins, and fats. Using photosynthesis, plants use sunlight to bind carbon to glucose, releasing oxygen (O_2)in the process. Through other metabolic processes, plants may convert glucose to other sugars, proteins, or fats. Animals obtain their carbon by eating and digesting plants, so carbon moves through the biotic environment through the trophic system. Herbivore eat plants, but are themselves eaten by carnivores.

Carbon returns to the physical environment in a number of ways. Both plants and animals respire, so they release CO_2 during respiration. Luckily for animals, plants just happen to consume more CO_2 through photosynthesis than they can produce. Another route of CO_2 back to the physical environment occurs through the death of plants and animals. When organisms die, decomposers consume their bodies. In the process, some of the carbon returns to the physical environment by way of fossilization. Some of it remains in the biological environment as other organisms eat the decomposers. But by far, most of the carbon returns to the physical environment through the respiration of CO_2.

Source: http://www.starsandseas.com

Review "Global Warming"

3- **Nitrogen Cycle (N-Cycle)**



Proteins, nucleic acids, and other organic chemicals contain nitrogen, so nitrogen is a very important atom in biological organisms. Nitrogen makes up 79% of Earth's atmosphere, but most organisms can not use nitrogen gas (N_2).

N_2 enters the trophic system through a process called **nitrogen fixation**. Bacteria found on the roots of some plants can fix N_2 to organic molecules, making proteins. Again, animals get their nitrogen by eating plants. But after this point, the nitrogen cycle gets far more complicated than the carbon cycle.

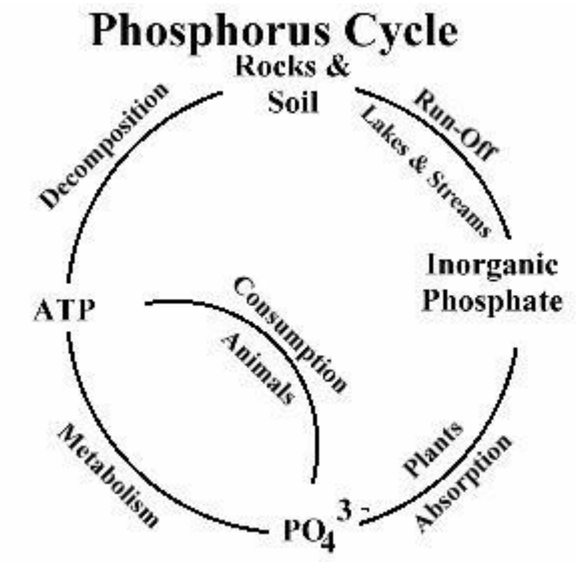
Animals releases nitrogen in their urine. Fish releases NH_3, but NH_3 when concentrated, is poisonous to living organisms. So organisms must dilute NH_3 with a lot of water. Living in water, fish have no problem with this requirements, but terrestrial animals have problems. They convert NH3 into urine, or another chemical that is not as poisonous as NH3. The process of releases NH_3 is called **ammonification**.

Because NH3 is poisonous, most of the NH_3 which is released is untouchable. But soil bacteria have the ability to assimilate NH_3 into proteins. These bacteria effectively eats the NH_3, and make proteins from it. This process is called **assimilation**.

Some soil bacteria does not convert NH_3 into proteins, but they make nitrate NO_3^- instead. This process is called **nitrification**. Some plants can use NO_3^-, consuming nitrate and making proteins. Some soil bacteria, however, takes NO_3^-, and converts it into N_2, returning nitrogen gas back into the atmosphere. This last process is called **denitrification**, because it breaks nitrate apart.

Source: http://www.starsandseas.com

4- Phosphorus Cycle **(P-Cycle)** **(** Source: http://www.starsandseas.com)



Phosphorus is the key to energy in living organisms, for it is phosphorus that moves energy between molecules, driving an enzymatic reaction, or cellular transport. Phosphorus is also the glue that holds (di-nucleic acid) DNA together, binding sugars together, forming the backbone of the DNA molecule.

Again, the keystone of getting phosphorus into trophic systems are plants. Plants absorb phosphorous from water and soil into their tissues, tying them to organic molecules. Once taken up by plants, phosphorus is available for animals when they consume the plants.

When plants and animals die, bacteria decomposes their bodies, releasing some of the phosphorus back into the soil. Once in the soil, phosphorous can be moved 100s to 1,000s of miles from were they were released by riding through streams and rivers. So the water cycle plays a key role of moving phosphorus from ecosystem to ecosystem.

In some cases, phosphorous will travel to a lake, and settle on the bottom. There, it may turn into sedimentary rocks, limestone, to be released millions of years later. So sedimentary rocks acts like a back, conserving much of the phosphorus for future eons.

Eutrophication is a process whereby water bodies, such as lakes, estuaries, or slow-moving streams receive excess nutrients that stimulate excessive plant growth (algae, periphyton attached algae, and nuisance plants weeds). This enhanced plant growth, often called an algal bloom, reduces dissolved oxygen in the water when dead plant material decomposes and can cause other organisms to die. Nutrients can come from many sources, such as fertilizers applied to agricultural fields, golf courses, and suburban lawns; deposition of nitrogen from the atmosphere; erosion of soil containing nutrients; and sewage treatment plant discharges. Water with a low concentration of dissolved oxygen is called hypoxic.

Development and the Environment

Development is to use and adapt our surrounding environment and its natural and human resources, effects and material and moral conditions and to utilize them for serving humans and their material and moral needs. Examples: First humans using leaves to cover their bodies; fishing, swimming and diving in water bodies and building ships.

Sustainable Development is a pattern of resource use that aims to meet human needs while preserving the environment so that these needs can be met not only in the present, but also for future generations. (Examples: German efforts to maintain the forests; preserving fish species; e.g. salmon fish in Canada.)

Environment and development in all of its forms (social, agricultural, industrial, human, economic and cultural) are closely linked, so that development cannot go on degraded environmental resource base. Examples: forest overharvesting and excessive groundwater withdrawal from wells.

Sustainable Economy: is one that produces wealth and provides jobs for many human generations without degradation the environment.

Fundamentals of Sustainability:

1- Reduction in society's use of nonrenewable natural sources,
2- In the long term, solution must be market based: it is more effective and cost effective for society to provide incentive to use alternatives or reduce the use of coal, gasoline, and other substances whose use results in pollution than to pass laws specifying how much pollution may be emitted.

Renewable Resources:
Are those that can be replaced within a few human generations.

Nonrenewable Resources:
Are those that are replaceable only in geological time scale.

Sustainable Energy Sources: (called Renewable Sources)

Hydropower, biomass or biofuels, geothermal, wave (or tides), wind, hydrogen, and solar energy.

Biofuels and wind energy now provide only 6% of the world's energy. They are growing at annual rates of 17 to 29%.

Biofuels from biomass: biomass energy includes wastes (include wood scrps, pulp and paper scrapes and municipal solid wastes including animal wastes), standing forests, and energy crops.

Geothermal: tap the natural heat from earth's magma. Energy may be used directly to heat buildings or to produce electricity from vented steam or by heating water to produce steam.

Pollution

Any change in the physical, chemical or biological properties of the main constituents of the environment (air, land and water) that affects the living organisms adversely.

Major Factors Leading to Increasing Pollution (of Human Type)

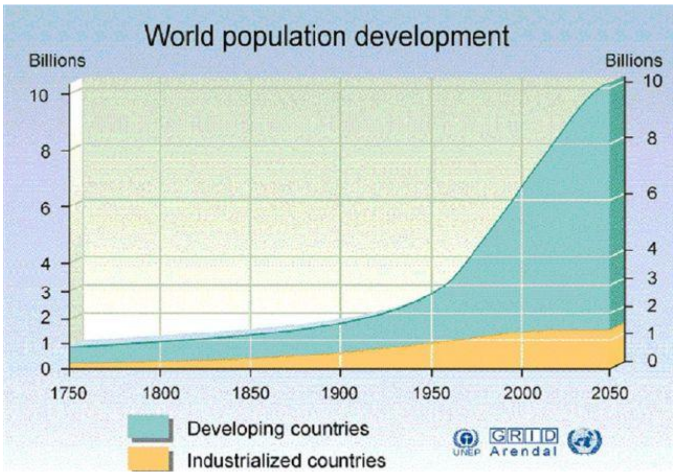
1. Population growth

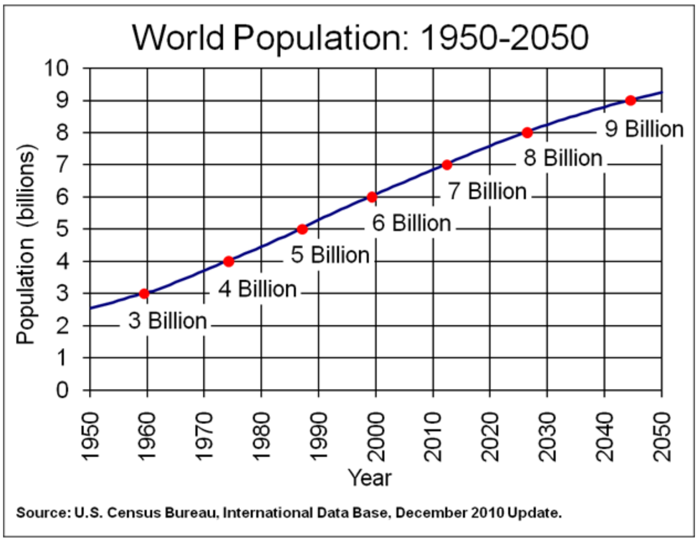
2. Industry

3. Increased Energy Consumption

4. Wars

1- ***Population growth***

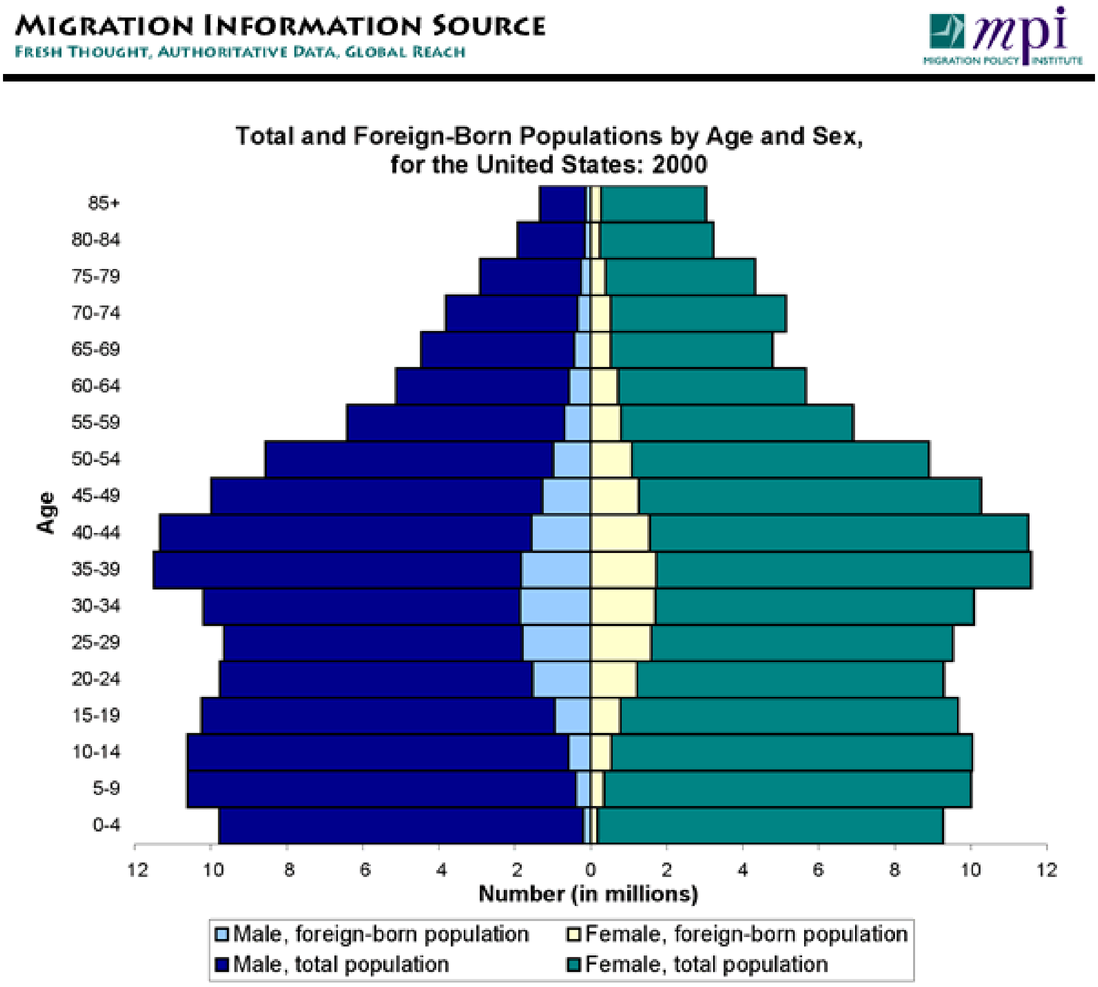




Saudi Arabia's population in 2006 is ≈ 27.5 millions.

The Population Pyramid

It is simply a representation of the human structure of a country/continent by age group and gender.



Total population: 281,421,906. Foreign-born population: 31,107,889. Source: Census 2000, 1% Public Use Micro-Sample Data.

Factors affecting the shape of the pyramid include: rates of births and deaths, wars, immigration and migration, health care, epidemic diseases, etc...

2. Industry

- Light industry; e.g. food industry, plastics, textile, etc.
- Heavy industry; e.g. weapons, construction, nuclear reactors, etc.

3. Increased Energy Consumption

- Non-renewable energy sources (traditional): fossil fuels: oil, natural gas, coal

- Renewable energy sources: solar, wind, water power (hydropower), tidal power

- Oil is considered the most important source of energy as its consumption rate is forms more than 40% of the total energy consumed

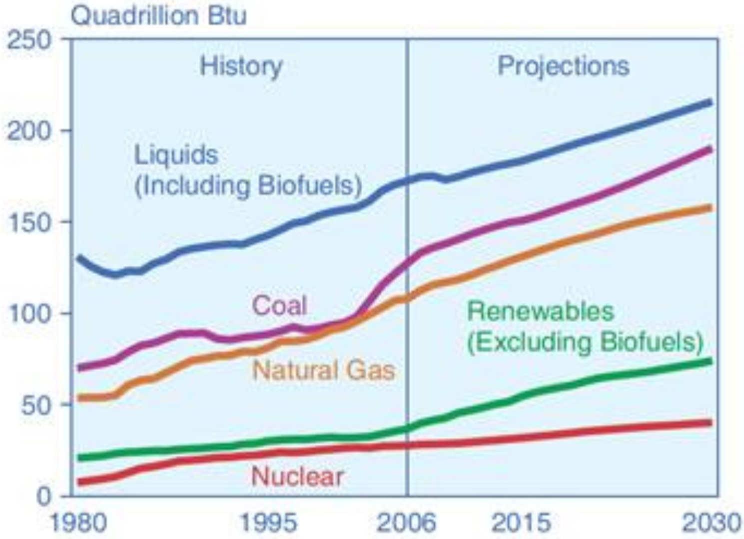
- The annual energy consumption has increased tenfold in the 20th century

(see Figures 14, 15 next page)

4. Wars

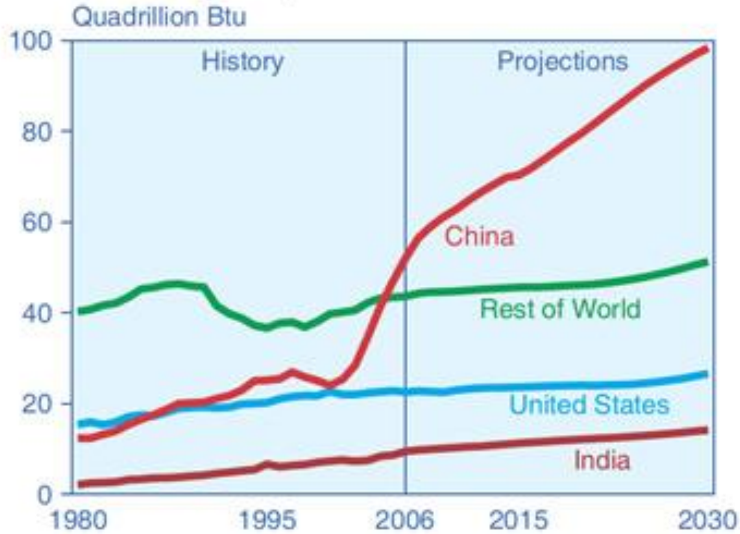
- Cold war versus field war
- Short term / long term
- Small scale (Iran/Iraq, Palestine/Israel) versus large scale (World Wars I and II)

Figure 14. World Marketed Energy Use by Fuel Type, 1980-2030



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).

Figure 15. Coal Consumption in Selected World Regions, 1980-2030



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).

GE 302 - Industry and the Environment

Chapter II

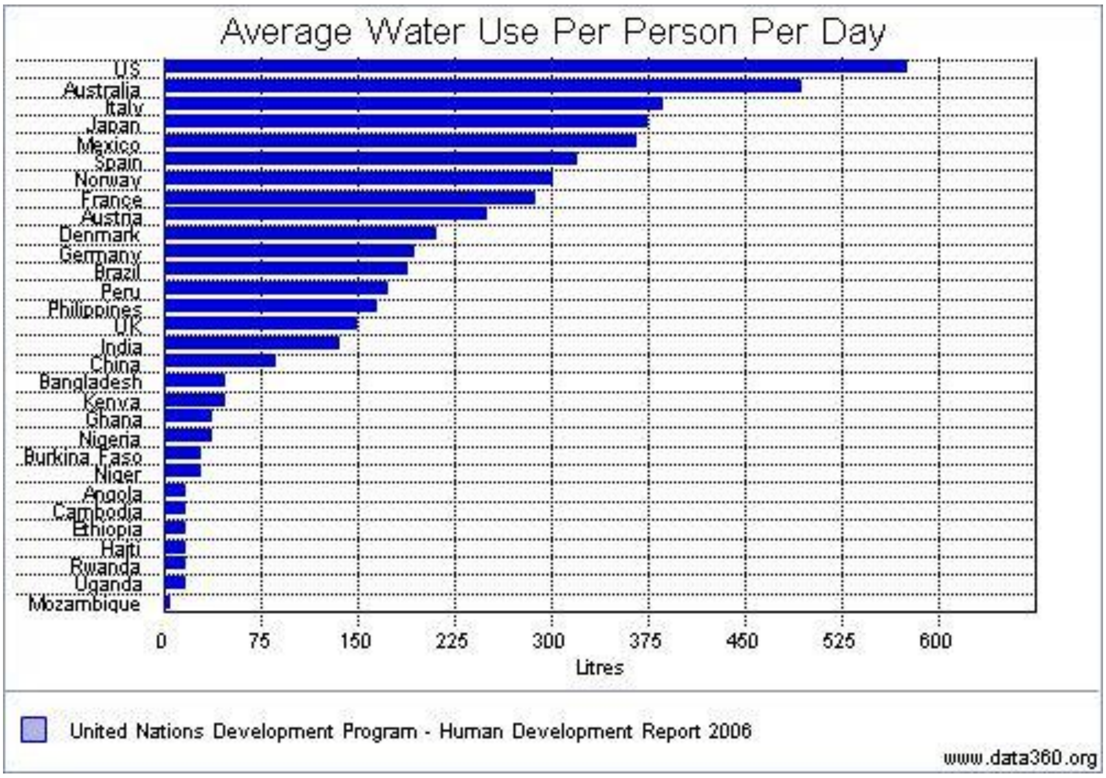
WATER POLLUTION

(Review Chapters 9, 10, and 11 of the textbook for more information)

TABLE OF CONTENTS

Water Quantity

Average water consumption rate in Saudi Arabia = 250 l/p.d
USA: 575 l/p.d UK: 150 l/p.d Rwanda: 20 l/p.d



Source: http://www.data360.org/dsg.aspx?Data_Set_Group_Id=757

Factors affecting the water consumption rate per person

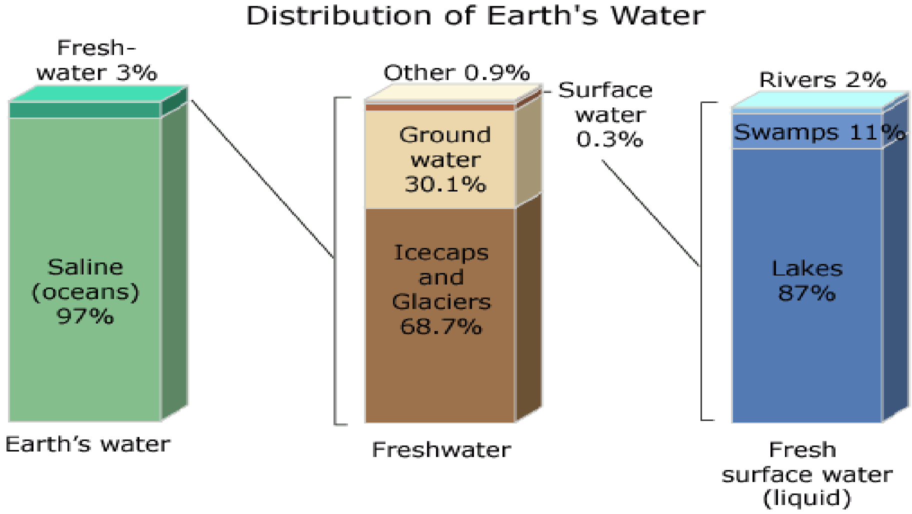
- Standard of living (car wash, swimming pools, gardening)
- Environmental awareness
- Weather conditions and season of the year
- Availability of water conservation programs
- Metering and pricing
- Social and cultural habits (bathing and showering frequency, ablution, food festivals)

Water Resources

- Surface water (rivers, lakes, springs)
- Groundwater (difficult to obtain)
- Desalinized Water (not that economic to produce)
- Treated Wastewater (not used for drinking and cooking)

Important Facts

- Water surfaces constitute 70% of the earth's surface
- Seas and oceans (saltwater) forms approximately 97% of the earth's water; i.e. only 3% is fresh water (sweet water)
- 78% of the fresh water is in glaciers, groundwater and the atmosphere, and 22% is in rivers, lakes and springs.



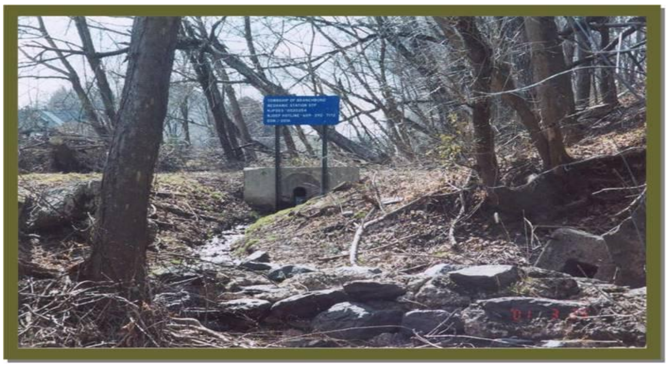
Water Sectors

- Domestic
- Agricultural
- Industrial

After water is consumed (used), it is disposed back into the environment (streams, seas, oceans, deserts) through point or non-point sources.

Point sources: Domestic sewage (municipal sewage) and industrial wastes.

Nonpoint sources (multiple discharge points): Urban and agricultural runoff.



To the left, photo showing the outlet of a drainage culvert as a point source of pollution.

To the left, photo showing an example of agricultural runoff as a non-point source of pollution.

Water Pollutants and Their Sources

(Sec. 9-2 Textbook)

Water Pollutants Sources

A- Oxygen-demanding materials Dissolved oxygen (DO)
Food waste and dead Plant and animal tissue that consume oxygen dissolved in water during its degradation thus depleting oxygen required for survival of fish, other marine animals and marine plants.

B- Nutrients: are considered pollutants when they become too much of a good thing. Nutrients of primary concern: Nitrogen and Phosphorus

Effect of nitrogen:
Nitrogen is detrimental to a receiving body for four reasons:

1- In high concentrations, ammonia in its unionized form is toxic to fish.
2- Ammonia, NH_3, in low concentrations, and nitrate, NO_3^-, serve as nutrients for excessive growth of algae.
3- The conversion of NH_4^+ to NO_3^- consumes large quantities of dissolved oxygen.
4- Formation of chloramines, during chlorination, which are more toxic.

Effect of Phosphorous:
Serves as a vital nutrient for the growth of algae; resulting in excess growth of algae. When algae die, become an oxygen-demanding organic material as bacteria seek to degrade those causing fish to die.

C- Pathogenic organisms (Pathogenic organisms): include bacteria, viruses, and protozoa.

- They are excreted by diseased persons or animals.
- They make the water unfit for drinking (i.e., non-potable).
- If the concentration of pathogens is sufficiently high, water may also be unsafe for swimming.

D- Suspended solids

E- Salts: the salts and other matter that don't evaporate are called total dissolved solids (TDS)

F- Pesticides; chemicals used by farmers, households, or industry to regulate and control various types of pets or weeds.

Major types of Pesticides: herbicides (used to kill unwanted plants), insecticides (used to kill unwanted insects that would otherwise destroy

crops, gardens, or structures), fungicides used to control the growth of fungi, many of which cause plant diseases).

G- Toxic metals: heavy metals (arsenic, cadmium, chromium, copper, nickel, lead, and mercury).

H- Heat

I- Nanoparticles: are those particles that have a dimension less than 100 nm

Contaminant Migration in Groundwater

Sec. 9-7(Textbook)

Contaminants can result from a variety of sources, including:

1- Discharge from improperly operated or located septic systems (Pathogens)
2- Leaking underground storage tanks, dumps and landfills
3- Improper disposal of hazardous and other chemical wastes
4- Spills from pipelines or transportation accidents
5- Recharge of groundwater with contaminated surface water
6- Salts from various chemical processes
7- Fertilizers and pesticides from agricultural operations (followed by agricultural runoff or drainage and infiltration of irrigation water)
8- Acidification of lakes

Categories used to describe Drinking-Water Quality

1- Physical: physical characteristics relate to the quality of water for domestic use and are usually associated with the appearance of water, its taste and odor. Physical parameters include: color, odor, temperature, and turbidity. Insoluble contents; such as solids, oil and grease, also fall in this category.

2- Chemical: The chemical characterization of drinking water includes the identification of its components and their concentrations.
   Chemical parameters associated with the organic content of waste-water include: biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), and total oxygen demand (TOD). Inorganic chemical parameters include: salinity, hardness, pH, acidity and alkalinity, as well as concentrations of ionized metals such as iron and manganese, and anionic entities such as chlorides, sulfates, sulfides, nitrates and phosphates.

3- Microbiological: Microbiological agents are important to public health and may also be significant in modifying the physical and chemical characteristics of water.
   Bacteriological parameters include: coliforms, fecal coliforms, specific pathogens, and viruses.

4- Radiological: Radiological factors must be considered in areas where the water may have come in contact with radioactive substances. The radioactivity of the water is of public health concern.

Temperature

Temperature is a measure of how cool or how warm the water is, expressed in degrees Celsius (C). Temperature is a critical water quality parameter, since it directly influences the amount of dissolved oxygen that is available to aquatic organisms. Water temperature that exceeds 18 degrees Celsius (for Class A Waters) has a deleterious effect on several fish species in streams. Salmonids, for example, prefer waters of approximately 12 to 14 degrees Celsius

Total Suspended Solids

Total Suspended Solids (TSS) is comprised of organic and mineral particles. In most rivers TSS is primarily composed of small mineral particles. TSS is often referred to as 'turbidity'. Higher TSS (>1000 mg L^{-1} may greatly affect water use by limiting light penetration. TSS, especially when the individual particles are small (< 63µm), carry many substances that are harmful or toxic.

Solids may be further subdivided into suspended and dissolved solids as well as organic (volatile) and inorganic (fixed) fractions.

Turbidity

Turbidity is a measure of the clarity of the water. It is the amount of solids suspended in the water. It can be in the form of minerals or organic matter. It is a measure of the light scattering properties of water, thus an increase in the amount of suspended solid particles in the water may be visually described as cloudiness or muddiness. Turbidity is measured in Nephelometric Turbidity Units (NTU).

Color

The presence of color in water does not necessarily indicate that the water is not potable. Color-causing substances such as tannins may be harmless. Color is not removed by typical water filters; however, slow sand filters can remove color, and the use of coagulants may also succeed in trapping the color-causing compounds within the resulting precipitate. Dissolved and particulate material in water can cause discoloration. Slight discoloration is measured in **Hazen Units** (HU). Impurities can be deeply colored as well, for instance dissolved organic molecules called tannins can result in dark brown colors, or algae floating in the water (particles) can impart a green color.

The color of a water sample can be reported as:

- *Apparent color* is the color of the whole water sample, and consists of color from both dissolved and suspended components.
- *True color* is measured after filtering the water sample to remove all suspended material.

Testing for color can be a quick and easy test which often reflects the amount of organic material in the water, although certain inorganic components like iron or manganese can also impart color.

Total dissolved solids (TDS)

Total dissolved solids is a measure of the amount of particulate solids that are in solution. This is an indicator of nonpoint source pollution problems associated with various land use practices. The TDS measurement should be obtained with the conductivity meter and is expressed in (mg/L).

Conductivity

Conductivity is the ability of the water to conduct an electrical current, and is an indirect measure of the ion concentration. The more ions present, the more electricity can be conducted by the water. This measurement is expressed in microsiemens per centimeter (uS/cm) at 25 degrees Celsius.

Fecal Coliform Bacteria

Fecal coliform bacteria are microscopic organisms that live in the intestines of all warm blooded animals, and in animal wastes or feces eliminated from the intestinal tract. Fecal coliform bacteria may indicate the presence of disease carrying organisms which live in the same environment as the fecal coliform bacteria. The measurement is expressed as the number of organisms per 100 mL sample of water (#/100mL).

pH

pH, or the "potential of hydrogen", is a measure of the concentration of hydrogen ions in the water. This measurement indicates the acidity or alkalinity of the water. On the pH scale of 0-14, a reading of 7 is considered to be "neutral". Readings below 7 indicate acidic conditions, while readings above 7 indicate the water is alkaline, or basic. Naturally occurring fresh waters have a pH range between 6 and 8. The pH of the water is important because it affects the solubility and availability of nutrients, and how they can be utilized by aquatic organisms.

Dissolved Oxygen

Dissolved oxygen is the amount of oxygen dissolved in water, measured in milligrams per liter (mg/L). This component in water is critical to the survival of various aquatic life in streams, such as fish. The ability of water to hold oxygen in solution is inversely proportional to the temperature of the water. For example, the cooler the water temperature, the more dissolved oxygen it can hold.

Biological Oxygen Demand (BOD)

Biological Oxygen Demand is a measure of how much oxygen is used by microorganisms in the aerobic oxidation, or breakdown of organic matter in the streams. Usually, the higher the amount of organic material found in the stream, the more oxygen is used for aerobic oxidation. This depletes the amount of dissolved oxygen available to other aquatic life. This measurement is obtained over a period of five days, and is expressed in mg/L.

Water Quality Standards

(p. 409 textbook)

Includes maximum contaminants levels (MCLs)

Examples of some national/international standards and institutions:

- Saudi Water Quality Standards
- US Water Quality Standards
- Environmental Protection Agency (EPA)
- World Health Organization (WHO)

Water Treatment

(p. 410 textbook)

Raw water and wastewater need to be treated before consumption of the first or disposal of the second. In some regions; e.g. Jordan, water may be so scarce that treated wastewater may be used as water resource. The degree to which water is treated depends upon the sector use.

Palatable water: is water that does not impart a taste or odor and is, therefore, pleasant to drink.

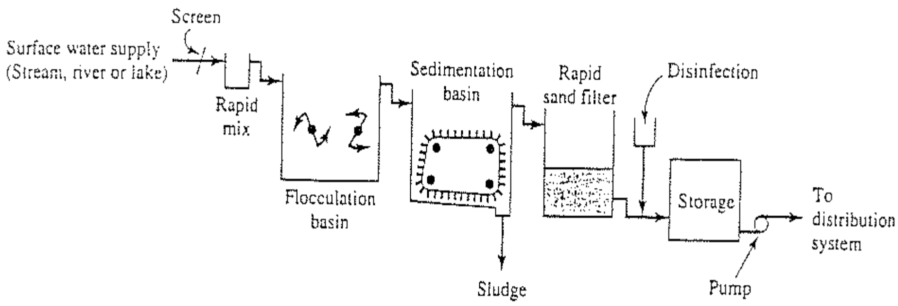
Potable water: is water that is free of chemicals, microorganisms, and other contaminants, and is, therefore, safe to drink, is called potable water.

Groundwater and Surface water (rivers, lakes, and reservoirs)

Water treatment facilities come in one of three general acceptable variations:
1) Limited treatment plants
2) Coagulation plants (Figure 10-2) (used to treat surface water).
3) Softening plants (Figure 10-3) (used to treat waters having a high hardness level, typically groundwater)

FIGURE 10-2

Flow diagram of a conventional surface-water treatment plant (coagulation plant).



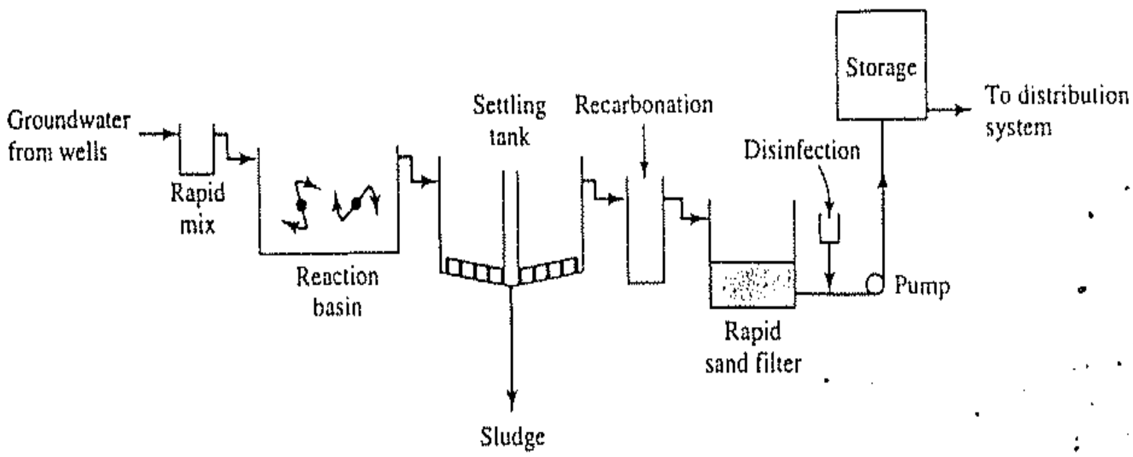


Figure10-3 Flow diagram of a water-softening plant

Note: Limited treatment plants generally have a high-quality water source.

Coagulation and flocculation processes are used to separate the suspended solids portion from the water.

Coagulation: transformation of a liquid into or as if a soft, semisolid, or solid mass

Flocculation: is a gentle mixing stage, increases the particle size from submicroscopic to visible suspended particles.

In a coagulation plant, rapid mixing, flocculation, sedimentation, filtration, and disinfection are employed to remove color, turbidity, taste and odors, and bacteria.

Disinfection, corrosion control, fluoridation, iron/manganese removal and softening are used for treatment of ground water as a raw water source.

More contamination means more extensive and expensive treatment.

Filtration is the removal of particles by sieving through a granular media.

Disinfection: is the addition of chemicals (usually chlorine, chloramines, or ozone) or the application of UV radiation to reduce the number of pathogenic organisms to levels that will not cause disease. The UV or ozone disinfection methods are more efficient in removing bacteria from the water over the chlorination process. Also, the chlorination process is less expensive than UV or Ozone also, the chlorination effect stays over in the system till the water reaches to the consumers, on the other hand, the UV and ozone are more localized process.

Recarbonation: is used to reduce the pH. It involves the addition of carbon dioxide to the water after the softening.

Wastewater

Wastewater flow: Wastewater and water flows about equal when:
– there is no lawn sprinkling
– Infiltration and exfiltration are not large
Generally 60% to 80 % of water becomes wastewater (Viessman and Hammer, 2005)

Residential flows

- ✓ 40 - 100 gpcd (150 – 380 l/p.d) (depends on type apartment or home) [Salvato, J. A. Environmental Engineering and Sanitation, 3rd Ed., Wiley, New York, 1982]
- ✓ Where possible use flow data from similar areas

Commercial

- ✓ 800 - 1500 gal/acre-day (748.32- 1403.1 m^3/km^2.d), typical [Metcalf & Eddy, Inc. *Wastewater Engineering: Treatment, Disposal, and Reuse*, 3rd Ed., revised by G. Tchobanoglous and Franklin L. Burton, McGraw-Hill, Inc., New York, 1991]

Industrial

- ✓ 1000 - 1500 gal/acre-day (935.4-1403.1m^3/km^2.d) (light industries)
- ✓ 1500 - 3000 gal/acre-day (1403.1 – 2806.2m^3/km^2.d) (medium industries)

  Source: [Metcalf & Eddy, Inc. *Wastewater Engineering: Treatment, Disposal, and Reuse*, 3rd Ed., revised by G. Tchobanoglous and Franklin L. Burton, McGraw-Hill, Inc., New York, 1991]

Characteristics of Domestic Wastewater

(Sec 11-2 in textbook)

A- Physical characteristics: Temperature and TDS

B- Chemical characteristics: BOD, COD, TKN, pH and P.

BOD (Biochemical Oxygen Demand) test: refer to pervious definition **(110-350 mg/l)**

COD (Chemical Oxygen Demand) test:

is a measure of the total quantity of oxygen required to oxidize all organic material into carbon dioxide and water (250-800 mg/l)

Total Kjeldahl nitrogen (TKN)

(pronounced "total kell dall nitrogen"): is a measure of total organic and ammonia nitrogen. TKN gives a measure the availability of nitrogen for

building cells, as well as the potential nitrogenous demand that will have to be satisfied (20 – 70 mg/l).

Phosphorous (4 – 12 mg/l).

pH

Typical composition of untreated domestic wastewater (Table 11-1 Textbook): Weak – medium – strong

The characteristics and levels of pollutants in industrial wastewater vary significantly from industry to industry.

Wastewater Treatment Standards

(Sec. 11-3 Textbook)

municipalities and industries are required to provide secondary treatment before discharging wastewater into natural water bodies.

U.S. Environmantal Protection Agency of Secondary Treatment (Table 11-6)

On-Site Disposal Systems (Sec 11-4 Textbook)

are used where municipal sewers are not available.

Examples: Septic tanks and constructed wetlands

Municipal Wastewater Treatment

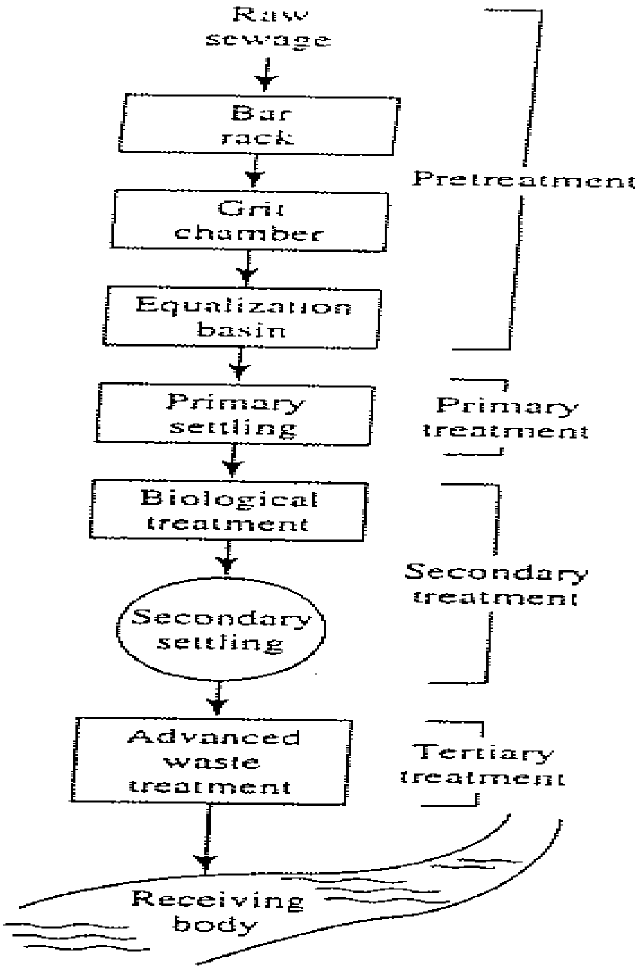
(Sec. 11-5 Textbook)

Sewage treatment, or **domestic wastewater treatment**, is the process of removing contaminants from wastewater and household sewage, both runoff (effluents) and domestic. It includes physical, chemical, and biological processes to remove physical, chemical and biological contaminants. Its objective is to produce a waste stream (or treated effluent) and a solid waste or sludge suitable for discharge or reuse back into the environment.

Pretreatment – Primary – Secondary – Tertiary – Disposal (See Figure 11-9)

FIGURE 11–9

Degrees of treatment.



1. Primary Treatment Processes (Clarification)

Clarification consists in removing all kind of particles, sediments, oil, natural organic matter and color from the water to make it clear.

A clarification step is the first part of conventional treatment for waste and surface water treatment. Usually, it consists in:

- Screening
- Physical and chemical treatment is a generic term for Coagulation-Flocculation
- Sedimentation or Flotation, upon particles properties and water type
- Fine filtration

For industrial effluents, Centrifugation is applied for heavy particles removal.

2. Secondary Treatment (Sec 11-8 Textbook)

Biological treatment of waste water and (domestic) sewage water is used to lower the organic load of organic compounds. There are two main categories:

- Aerobic treatment
- Anaerobic treatment

In aerobic systems the water is aerated with compressed air (in some cases oxygen). Anaerobic systems run under oxygen free conditions.

The majority of municipal plants treat the settled sewage liquor using aerobic biological processes.

A variety of approaches is used. The most common approaches for municipalities are: Trickling filter and the Activated sludge process. Lagoons are employed when wastewater flows are not large and land space is available.

Secondary treatment systems include

- **Fixed-film** or
- **Suspended-growth**.

Fixed-film (attached growth system) treatment process including trickling filter and rotating biological contactors where the biomass grows on media and the sewage passes over its surface.

In **suspended-growth** systems, such as activated sludge, the biomass is well mixed with the sewage and can be operated in a smaller space than fixed-film systems that treat the same amount of water. However, fixed-film systems are more able to cope with drastic changes in the amount of biological material and can provide higher removal rates for organic material and suspended solids than suspended growth systems.

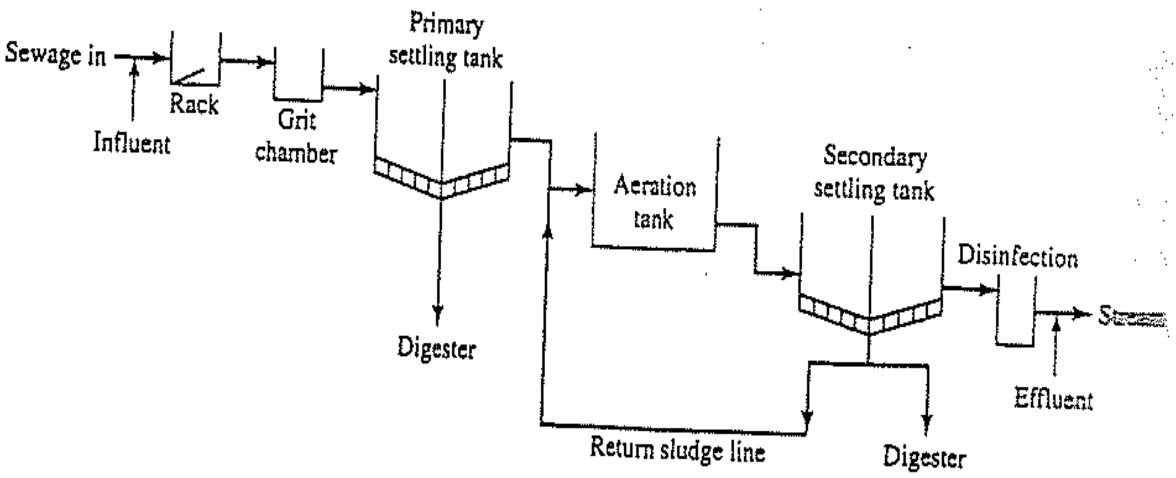
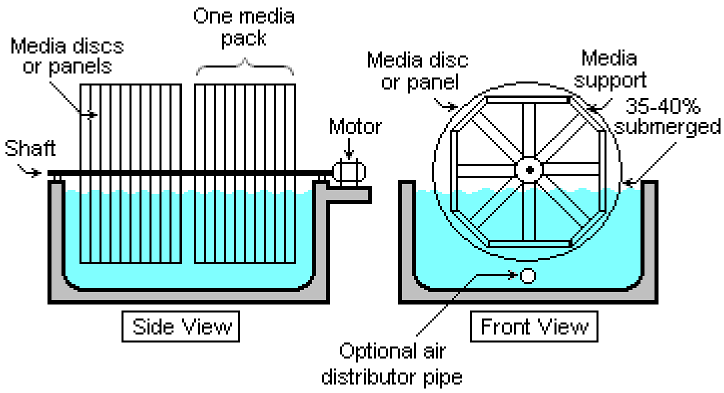


Figure 11-12: Conventional Activated Sludge Treatment Plant



Schematic diagram of a typical rotating biological contactor (RBC). The treated effluent clarifier/settler is not included in the diagram (refer to Figure 11-18 in the textbook)

Disinfection: (Sec 11-9 Textbook)
It is the process that eliminates many or all pathogenic microorganisms with the exception of bacterial endospores.

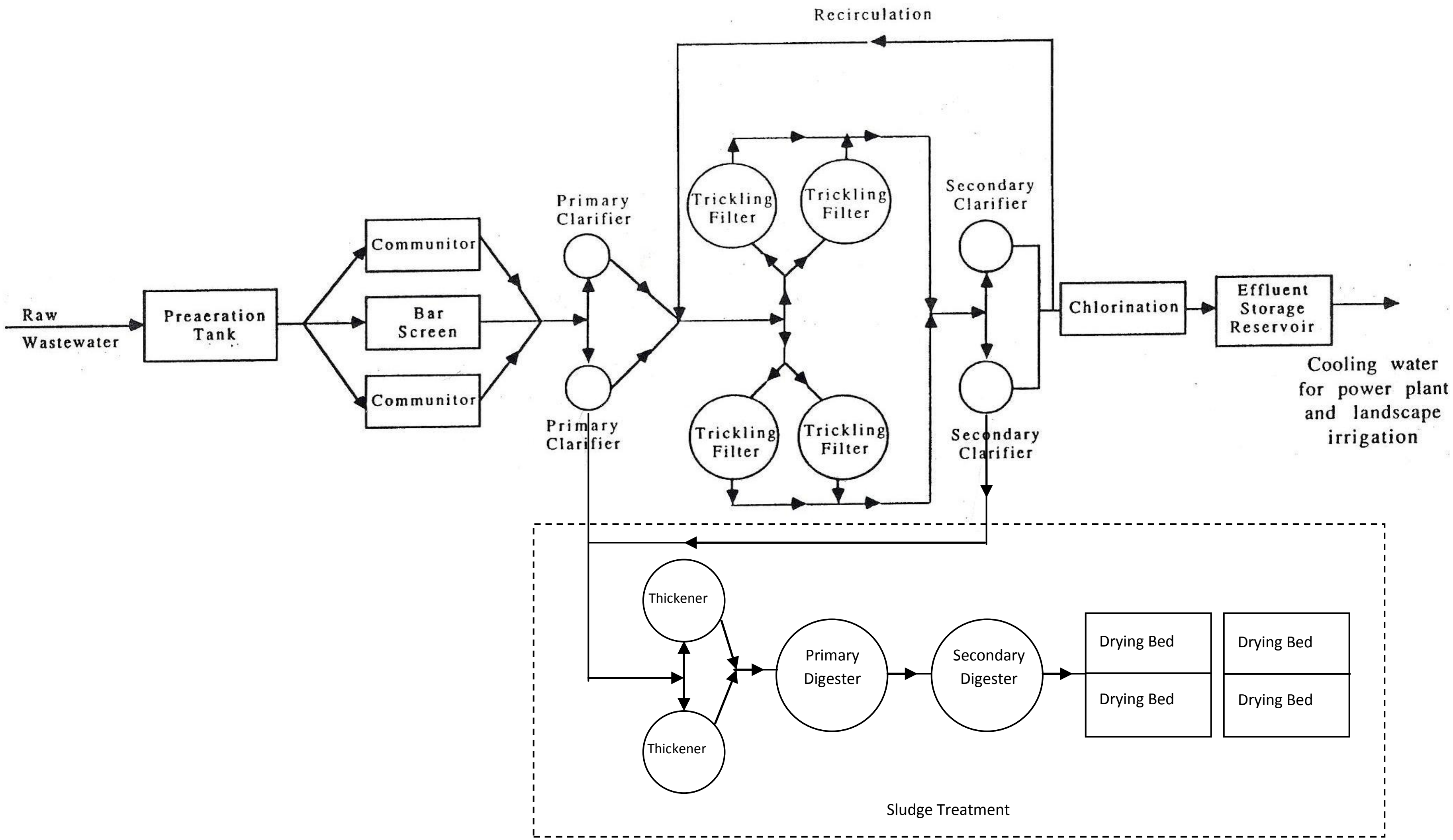
Sterilization is the complete elimination or destruction of all forms of microbial life (i.e., involves killing 100% of vegetative microorganisms, including associated endospores).

3. Advanced wastewater Treatment (Sec 11-10 Textbook)

A- Filtration
B- Carbon adsorption
C- Phosphorus removal

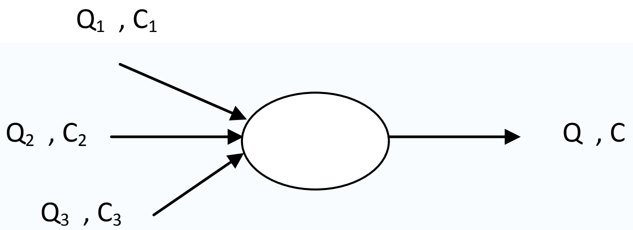
Nitrogen control: nitrogen may need to be removed from wastewater (ww) to help control algal growth in the receiving body. In addition, nitrogen in the form of ammonia exerts an oxygen demand and can be toxic to fish. Removal of nitrogen can be accomplished either biologically or chemically. The biological process is called nitrification-denitrification. The chemical process is called ammonia stripping.

The following page presents a schematic of King Saud University Wastewater Treatment Plant as an example.



Schematic diagram of King Saud University Wastewater Treatment Plant.

Pollution of Stream Lines



$Q = Q_1 + Q_2 + Q_3$

$C = \sum(QC) / \sum Q = (Q_1 C_1 + Q_2 C_2 + Q_3 C_3) / (Q_1 + Q_2 + Q_3)$

Example:

A wastewater treatment plant is discharging its effluents to a river. Water flow rates and characteristics are as follow:

	River (before mixing point)	Wastewater Treatment Plant
Flow rate (m^3/h)	20,000	3100 (24 h/day)
TDS (mg/L)	360	420

At the point of discharge (assuming complete mixing), determine the concentration of TDS.

Solution:

TDS=[(20,000x360)+(3100x420)] / [20,000+3100]= 368 mg/L

Note: If a factory is discharging its wastewater during certain hours every day, the factory can reduce the flow rate by using an equalization tank. The new flow rate could be calculated as follows:

Equalized flow rate = Total volume discharged daily / 24

= (original flow rate × factory working hours) / 24

Example

A wastewater treatment plant and a factory are discharging their effluents to a river at the same point. Water flow rates and characteristics are as follows:

	River (before mixing point)	Wastewater Treatment Plant	Factory
Flow rate (m^3/h)	20,000	3100	800 (during the working hours)
Working hours daily		24	6
COD (mg/L)	14	70	420
TDS (mg/L)	360	420	2600

At the point of discharge (assuming complete mixing), determine the concentration of TDS for the following conditions:

A. Within and off (out) the working hours of the factory.
B. The use of the factory for an equalization tank.

Solution:

A.
Within the working hours of the factory, TDS=[(20,000x360)+(3100x420)+(800x2600)] / [20,000+3100+800]=442.8 mg/L

Off the working hours of the factory, TDS=[(20,000x360)+(3100x420)] / [20,000+3100]=368.1 mg/L

B. If the factory utilize an equalization tank:
Flow rate from the factory will be=800x(6/24)= 200 m^3/h

TDS=[(20,000x360)+(3100x420)+(200x2600)] / [20,000+3100+200]=387.2 mg/L

Water Pollution with Oil Spill

An **oil spill** is the release of a liquid petroleum hydrocarbon into the environment due to human activity, and is a form of pollution. The term often refers to marine oil spills, where oil is released into the ocean or coastal waters. The oil may be a variety of materials, including crude oil, refined petroleum products (such as gasoline or diesel fuel) or by-products, ships' bunkers, oily refuse or oil mixed in waste. Spills take months or even years to clean up.

Photo showing an oil ship wreck in the open ocean. The damage caused the formation of the shown oil spill.

Environmental Effects

A- Damage to Fisheries:

Oil spills present the potential for enormous harm to deep ocean and coastal fishing and fisheries. Harms include: fish mass mortality and contamination, poisoning ocean organic substrate and shutting down fishing enterprises.

B- Damage to Wildlife:

Wildlife other than fish and sea creatures; including mammals, reptiles, amphibians, and birds that live in or near the ocean, are also poisoned by oil waste.

C- Damage to Recreation:

Coastal areas are usually thickly populated and attract many recreational activities; for example fishing, boating, diving, swimming, natural parks and preserves, beaches, …etc.

Clean Up an Oil Spill

The techniques used to clean up an oil spill depend on oil characteristics and the type of environment involved; for example, open ocean, coastal, or wetland.

Pollution-control measures include:

a) containment and removal of the oil (either by skimming, filtering, or *in situ* combustion),

b) dispersing it into smaller droplets to limit immediate surficial and wildlife damage,

c) biodegradation (either natural or assisted), and

d) normal weathering processes.

Photo: Workers clean up an oil refinery spill that polluted Anacortes Bay, Washington. The floating ring of absorbent pads trailing behind the boat is being used to contain some of the oil that has spilled.

Methods for Cleaning up

1) Booms

Oil boom is a floating barrier, which is used in cleaning up oil on the surface of the water. Boom is used to contain oil, to collect oil, as a barricade to exclude oil from a certain area; to absorb oil; and to deflect oil. Floating booms are mechanical barriers that extend above and below the surface of the water to stop the flow of oil.

2) Oil Spill Skimmers

Skimming is a process of removing oil from the top of the water surface. This is achieved by the use of various mechanical devices such as pumps, vacuum systems etc. The efficiency of a skimmer depends upon the sea and weather conditions. As the water conditions become rougher the skimmer starts to pull in more water along with oil.

3) Sorbents

Sorbent booms and barriers are used to absorb a moving oil slick. They only work well when a slick is thin, because once their surfaces are saturated, they cannot absorb anymore.

4) In-situ Burning

Through controlled burning of the oil can effectively remove the oil slick. This method is called in-situ burning. In-situ burning can approximately remove around 100-gallons/day/square foot of surface area

under excellent weather conditions. In this way, bird, marine mammals, turtles and sensitive coast areas are being spared from the effects of the spill.

5) Bioremediation

Oil, like many natural substances, will biodegrade over a period of time into simple compounds such as carbon dioxide, water and biomass. Bioremediation is the term used to describe a range of processes, which can be used to accelerate natural biodegradation.

6) Manual Cleanup

The other best way to clean up oil once it has hit the shore is by manual cleanup. Since oil has chances of spreading and getting mixed with the soil or sand on the shore, the best method to contain oil spread is by manual methods.

7) Dispersants

Dispersants are chemicals, which have components of surface-active agents called surfactants. The dispersants aids in the breaking up of the oil slick into smaller droplets.

Marine Oil Spill Prevention

Preventing and preparing for spills

Spill prevention and preparedness is an essential part of the program. Preparedness tools include geographic response plans, drills and exercises, and vessel and facility plans.

a) Geographic response plans

Geographic response plans detail geographic information, equipment requirements and locations, as well as preferred response activities for particular sections of the Willamette and Columbia rivers and coast. Each plan focuses on a specific river segment and includes identification of aquatic and wildlife habitats and water withdrawal points and uses, resource protection and spill containment strategies, maps, locations of necessary materials, and other information. Government agencies, river users and response providers collaborate to develop these plans.

b) Drills and exercises

Regulatory agencies often require participation in and attend response and cleanup exercises as an observer or active participant. Incident management teams, emergency responders and relevant staff all gain valuable training and insights from drills and exercises as well as actual incidents.

c) Vessel and facility plans

Vessels traveling through navigable waters and oil handling facilities must have oil spill response plans. These plans provide clear instructions for responding to oil spills. Regulatory agencies review and approve each of the plans.

GE 302 - Industry and the Environment

Chapter III – Air Pollution

Contents

GE 302 - Industry and the Environment

Chapter III – Air Pollution

(Review Chapter 12 of the Textbook for more information)

Introduction

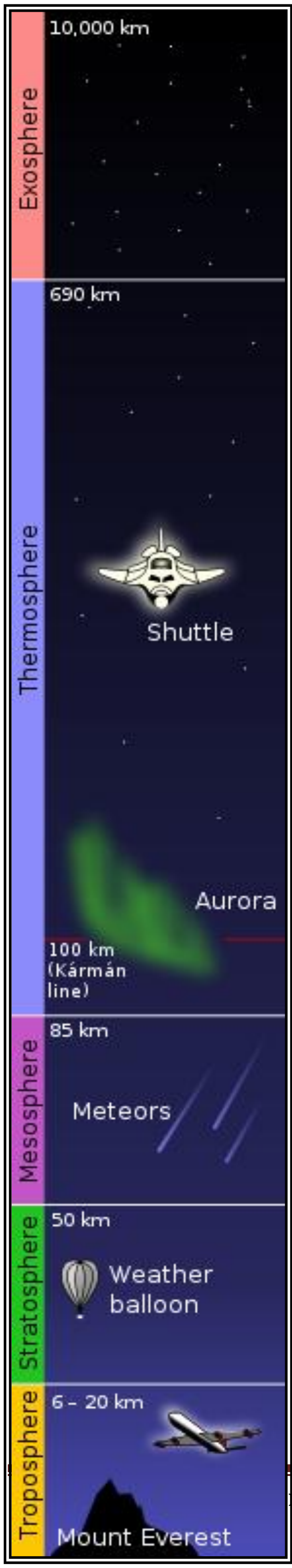
The **Earth's atmosphere** is a layer of gases surrounding the planet that is retained by gravity. The atmosphere protects life by:

1. absorbing ultraviolet solar radiation, which may harm the skin of living organisms,
2. warming the surface through heat retention (greenhouse effect), and
3. reducing temperature extremes between day and night.

Dry air contains roughly (by volume) 78.08% nitrogen, 20.95% oxygen, 0.93% argon which together constitute the "major gases" of the atmosphere. The remaining gases often are referred to as "trace gases" 0.038% carbon dioxide, and trace amounts of other gases. Air also contains a variable amount of water vapor, on average around 1%.

Greenhouse gases includes: water vapor, carbon dioxide, methane, nitrous oxide, and ozone. Filtered air includes trace amounts of many other chemical compounds. Many natural substances may be present in little amounts in an unfiltered air sample, including dust, pollen and spores, sea spray, volcanic ash, and meteoroids. Various industrial pollutants also may be present, such as chlorine (elementary or in compounds), fluorine (in compounds), elemental mercury, and sulfur (in compounds such as sulfur dioxide [SO_2]).

Earth's atmosphere can be divided into five main layers according to whether temperature increases or decreases with altitude. From lowest to highest, these layers are: Troposphere, Stratosphere, Mesosphere, Thermosphere and Exosphere.



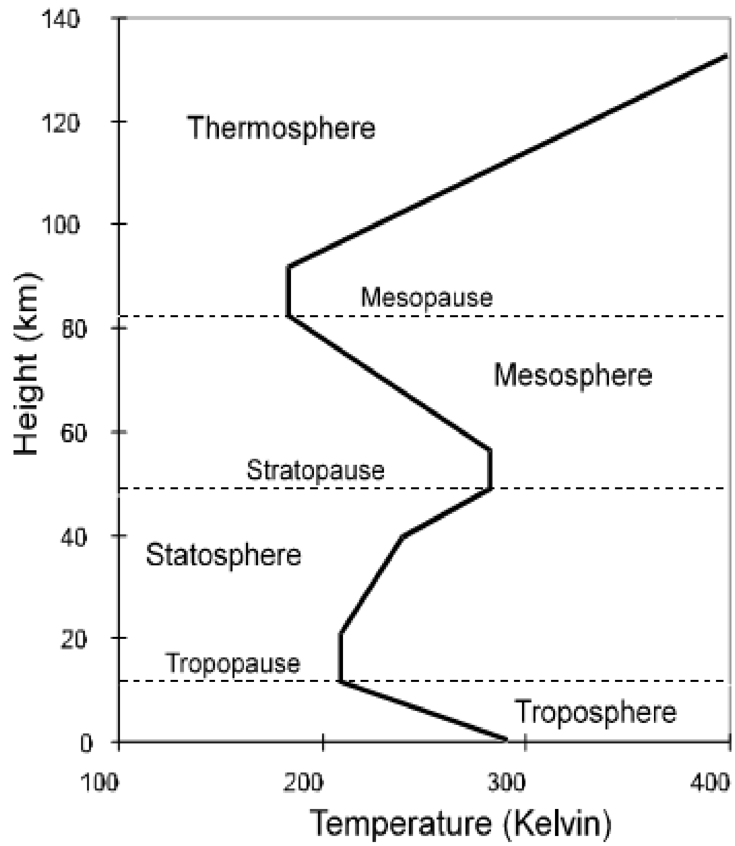


Figure 3.1: Temperature variation across the layers of the atmosphere.

Figure 3.2: Principal layers of the atmosphere (average thicknesses and activities).

Troposphere

The troposphere begins at the surface and extends to between 7 km at the poles and 17 km at the equator, with some variation due to weather. The troposphere is mostly heated by transfer of energy from the surface, so on average the lowest part of the troposphere is warmest and temperature decreases with altitude, which promotes vertical mixing. The troposphere contains roughly 80% of the mass of the atmosphere.

Stratosphere

The stratosphere extends to about 51 km. Temperature increases with height, which restricts turbulence and mixing.

Mesosphere

The mesosphere extends to 80–85 km. It is the layer where most meteors burn up upon entering the atmosphere. Temperature decreases with height in the mesosphere.

Thermosphere

Temperature increases with height in the thermosphere. The temperature of this layer can rise to 1,500 °C. The International Space Station orbits in this layer, between 320 and 380 km. Its height varies with solar activity and ranges from about 350 to 800 km.

Exosphere

Is the outermost layer of Earth's atmosphere. The exosphere is mainly composed of hydrogen and helium.

Other layers

Within the five principal layers determined by temperature are several layers determined by other properties. The ozone layer is contained within the stratosphere. In this layer ozone concentrations are about 2 to 8 parts per million, which is much higher than in the lower atmosphere but still very small compared to the main components of the atmosphere. It is mainly located in the lower portion of the stratosphere from about 15 to 35 km, though the thickness varies seasonally and geographically. About 90% of the ozone in our atmosphere is contained in the stratosphere.

Definition of Air Pollution

1) Air pollution means the presence in the atmosphere of one or more air contaminants thereof in such quantities and of such duration as are or may tend to be hazard to human, plant, animal life, or property.

   Contaminants include smoke, vapors, charred paper, dust, soot, grime, carbon fumes, gases, mist, odors, particulate matter, radioactive materials, or noxious chemicals, or any other material in the atmosphere. Stratospheric ozone depletion is believed to be caused by air pollution (chiefly from chlorofluorocarbons)

2) .

Worldwide, air pollution is responsible for large numbers of deaths and respiratory disease. Enforced air quality standards, like the Clean Air Act use by governments, have reduced the presence of pollutants. While major stationary sources are often identified with air pollution, the greatest source of emissions is actually mobile sources, principally the automobile.

Atmospheric pollution occurs because the release of air pollutants takes place at a rate much faster than they can be accommodated by the environment and removed from the atmosphere without causing serious harm.

The Six Common Air Pollutants

The Clean Air Act requires EPA to set National Ambient Air Quality Standards for six common air pollutants. These commonly found air pollutants (also known as "criteria pollutants") are found all over the United States. They are:

1) ground-level ozone,
2) particle pollution (often referred to as particulate matter),
3) carbon monoxide,
4) sulfur oxides,
5) nitrogen oxides, and
6) lead.

These pollutants can harm human health and the environment, and cause property damage; these pollutants have science-based guidelines/standards based on human health and environmental criteria for setting permissible levels. The set of limits based on human health is called primary standards, the limits intended to prevent environmental and property damage are called secondary standards.

1) **Ozone** (O_3) is a gas composed of three oxygen atoms. It is not usually emitted directly into the air, but at ground-level is created by a chemical reaction between oxides of nitrogen (NOx) and volatile organic compounds (VOC) in the presence of sunlight. Ozone has the same chemical structure whether it occurs miles above the earth or at ground-level and can be "good" or "bad," depending on its location in the atmosphere.

   In the earth's lower atmosphere, ground-level ozone is considered "bad." Motor vehicle exhaust and industrial emissions, gasoline vapors, and chemical solvents as well as natural sources emit NOx and VOC that help form ozone. Ground-level ozone is the primary constituent of smog. Sunlight and hot weather cause ground-level ozone to form in harmful concentrations in the air. As a result, it is

known as a summertime air pollutant. Many urban areas tend to have high levels of "bad" ozone, but even rural areas are also subject to increased ozone levels because wind carries ozone and pollutants that form it hundreds of miles away from their original sources.

"Good" ozone occurs naturally in the stratosphere approximately 10 to 30 miles above the earth's surface and forms a layer that protects life on earth from the sun's harmful rays.

2) "Particulate matter," also known as particle pollution or PM, is a complex mixture of extremely small particles and liquid droplets. Particle pollution is made up of a number of components, including acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles.

The size of particles is directly linked to their potential for causing health problems. EPA is concerned about particles that are 10 micrometers in diameter or smaller because those are the particles that generally pass through the throat and nose and enter the lungs. Once inhaled, these particles can affect the heart and lungs and cause serious health effects. EPA groups particle pollution into two categories:

- "Inhalable coarse particles," such as those found near roadways and dusty industries, are larger than 2.5 micrometers and smaller than 10 micrometers in diameter.
- "Fine particles," such as those found in smoke and haze, are 2.5 micrometers in diameter and smaller. These particles can be directly emitted from sources such as forest fires, or they can form when gases emitted from power plants, industries and automobiles react in the air.

3) **Carbon Monoxide** or CO is a colorless and odorless gas that is formed when carbon in fuel is not burned completely. It is a component of motor vehicle

exhaust which contributes about 56 percent of all CO emissions. Other non-road engines and vehicles (such as construction equipment and boats) contribute about 22 percent of CO emissions. Higher levels of CO generally occur in areas with heavy traffic congestion. In cities, 85 to 95 percent of all CO emissions may come from motor vehicle exhaust. Other sources of CO emissions include industrial processes such as metals processing, chemical manufacturing, residential wood burning, natural sources (e.g. forest fires). Indoor CO sources are commonly woodstoves, gas stoves, cigarette smoke, unvented gas and kerosene space heaters.

The highest levels of CO in the outside air typically occur during the colder months of the year when inversion conditions are more frequent, air pollution becomes trapped near the ground beneath a layer of warm air leading to the formation of smog being trapped close to the ground, with possible adverse effects on health. An inversion can also suppress convection by acting as a "cap"(stratification).

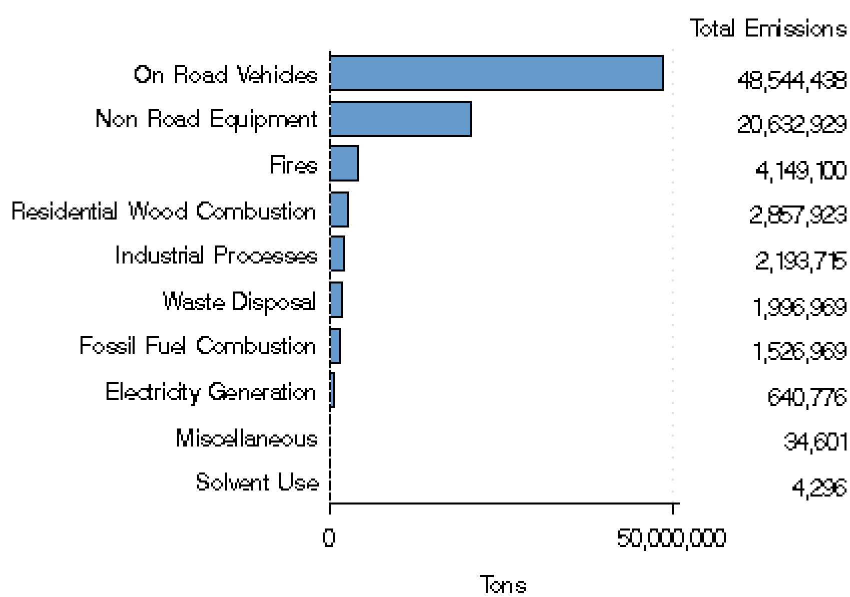


Figure 3.3: US Carbon Monoxide Emissions by Source Sector in 2005.

Impacts of Carbon Monoxide:

- It can cause harmful health effects by reducing oxygen delivery to the body organs; for example the heart and brain, and tissues.

- **Central Nervous System Effects**

Even healthy people can be affected by high levels of CO. People who breathe high levels of CO can develop vision problems, reduced ability to work or learn, reduced manual dexterity and difficulty performing complex tasks. At extremely high levels, CO is poisonous and can cause death.

- Smog formation: CO contributes to the formation of smog ground-level ozone, which can trigger serious respiratory problems.

- **Carboxyhemoglobin:**

Carboxyhemoglobin (COHb) is a stable complex of carbon monoxide and hemoglobin that forms in red blood cells when carbon monoxide is inhaled, it hinders delivery of oxygen to the body.

Hemoglobin binds to carbon monoxide preferentially compared to oxygen (approx 240:1), so effectively, COHb will not release the carbon monoxide, and therefore hemoglobin will not be available to transport oxygen from the lungs to the rest of the body. Humans should survive with very small amounts of COHb in their blood with very little or no observable effects. COHb has a half-life in the blood of 4 to 6 hours, but this can be reduced to 40 minutes with administration of 100% oxygen.

In large quantities, the effect of COHb to humans is lethal, known medically carbon monoxide poisoning. However in smaller quantities, COHb leads to oxygen deprivation of the body causing tiredness, dizziness, unconsciousness and increases risk of blood clots.

Tobacco smoking (carbon monoxide inhalation) raises the blood levels of COHb increases the risk of having an ischemic stroke., furthermore pregnant smokers may give birth to babies of a lower birth mass as fetal hemoglobin takes up carbon monoxide more readily than in an adult, therefore the fetus of a smoker will suffer from mild hypoxia potentially retarding its development.

$$\%COHb = 0.005 \times [CO]^{0.85} [T \times F]^{0.63}$$

[CO] = CO concentration in air (ppm)

T = time of exposure (min)

F = exposed person activity factor (1 for resting, 2 for walking, or 3 for hard work)

%COHb of less than 1% means no effects can be noticed. If %COHb exceeds 50%, it might cause death.

Example: How long does it need to reach to a COHb of 11.3% in the blood of a hard working person if; [CO] = 25 ppm and air temperature = 32 ºC?

Solution: $\%COHb = 0.005 \times [CO]^{0.85} [T \times F]^{0.63}$

$11.3 = 0.005 \times [25]^{0.85} [T \times 3]^{0.63}$

T = 913.5 minutes =15.23 hours

4) **Nitrogen dioxide** (NO_2) is one of a group of highly reactive gasses known as "oxides of nitrogen," or "nitrogen oxides (NOx)." Other nitrogen oxides include nitrous acid and nitric acid. While EPA's National Ambient Air Quality Standard covers this entire group of NOx, NO_2 is the component of greatest interest and the indicator for the larger group of nitrogen oxides. NO_2 forms quickly from emissions from cars, trucks and buses, power plants, and off-road equipment. In addition to contributing to the formation of ground-level ozone, and fine particle pollution, NO_2 is linked with a number of adverse effects on the respiratory system.

   EPA first set standards for NO_2 in 1971, setting both a primary standard (to protect health) and a secondary standard (to protect the public welfare) at 0.053 parts per million (53 ppb), averaged annually.

5) **Sulfur dioxide**, or SO_2, belongs to the family of sulfur oxide gases (SOx). These gases dissolve easily in water. Sulfur is prevalent in all raw materials, including crude oil, coal, and ore that contains common metals like aluminum, copper, zinc, lead, and iron.

   SOx gases are formed when fuel containing sulfur, such as coal and oil, is burned, and when gasoline is extracted from oil, or metals are extracted from ore.

   SO_2 dissolves in water vapor to form acid, and interacts with other gases and particles in the air to form sulfates and other products that can be harmful to people and their environment.

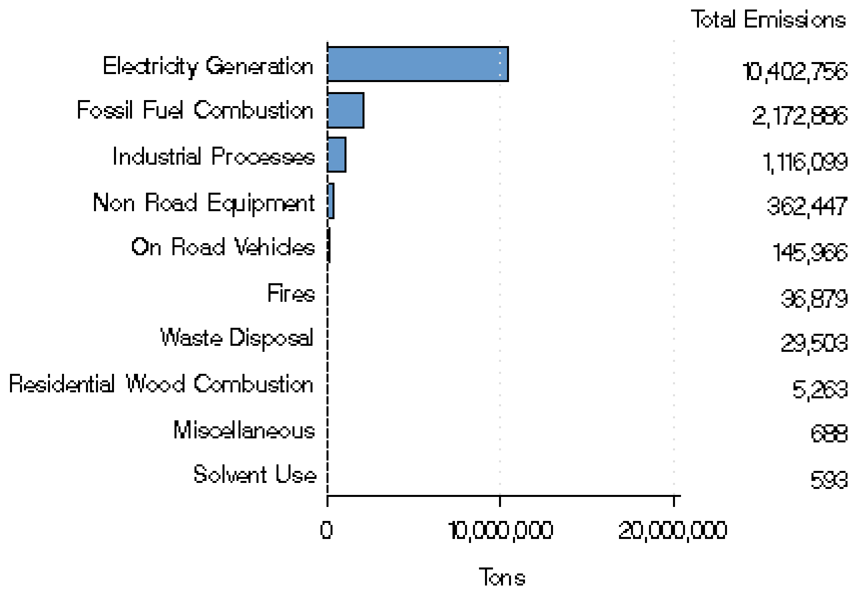


Figure 3.4: US Sulfur Dioxide Emissions by Source Sector in 2005.

Impacts of Sulfur Dioxide:

SO2 causes a wide variety of health and environmental impacts because of the way it reacts with other substances in the air. Particularly sensitive groups include people with asthma who are active outdoors and children, the elderly, and people with heart or lung disease.

- **Respiratory illness**, particularly in children and the elderly, and in the longer-term exposures to high levels of SO_2 gas and particles aggravate existing heart and lung disease and are associated with increased respiratory symptoms and disease, difficulty in breathing, and premature death. Figure 3.4 displays the effects of pollutants on humans.

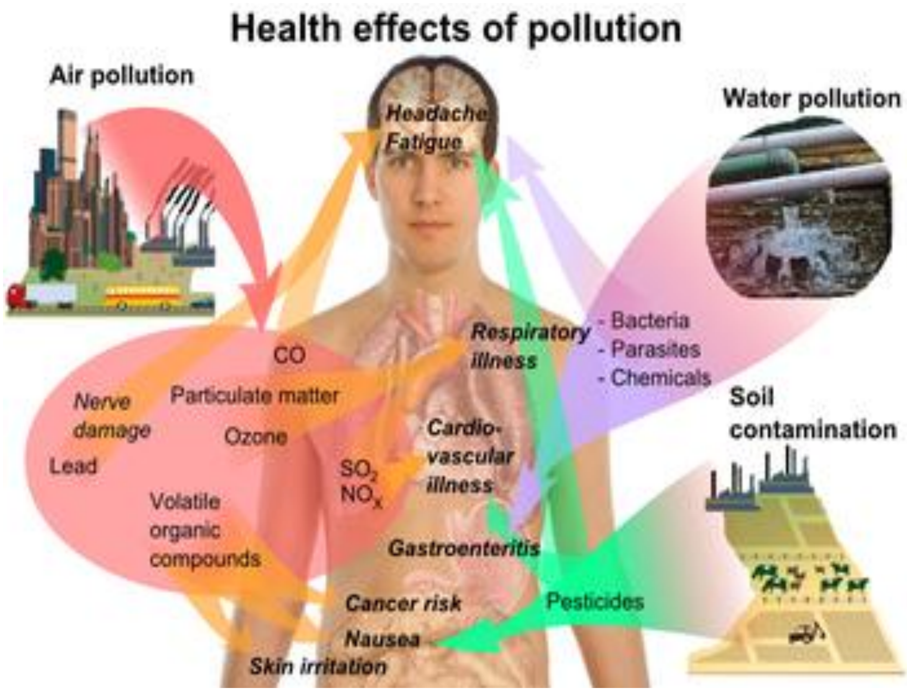


Figure 3.4: Rrespiratory disorders due to air and other types of pollution.

- **Visibility Impairment** Sulfate particles are the major cause of reduced visibility in many parts of the US; particularly in national parks where haze occurs when light is scattered or absorbed by particles and gasses in the air.

High levels of SO_2 (peak levels) emitted over a short period, such as a day, can be particularly problematic for people with asthma causing temporary breathing difficulty. People are encouraged to learn about the types of industries in their communities and to work with local industrial facilities to address pollution control equipment failures or process upsets that could result in peak levels of SO_2.

- Formation of **acid rain,** which is rain or any other form of precipitation that is unusually acidic, i.e. elevated levels of hydrogen ions (low pH). Acid rain is mostly caused by emissions of compounds of sulfur, nitrogen, and carbon as displayed in figure 3.5, which react with the water molecules in the atmosphere to produce acids, which fall to earth as rain, fog, snow, or dry particles. Some may be carried by the wind for hundreds of miles.

However, it can also be caused naturally by the splitting of nitrogen compounds by the energy produced by lightning strikes, or the release of sulfur dioxide into the atmosphere by phenomena of volcano eruptions.

Impacts of acid rain:

- **Plant and Water Damage** - Acid rain damages forests and crops (Figure 3.6), changes the makeup of soil, and makes lakes and streams acidic and unsuitable for fish. Continued exposure over a long time changes the natural variety of plants and animals in an ecosystem.

- **Aesthetic Damage** - SO_2 accelerates the decay of building materials and paints, including irreplaceable monuments, statues, and sculptures that are part of our nation's cultural heritage (Figure 3.7).

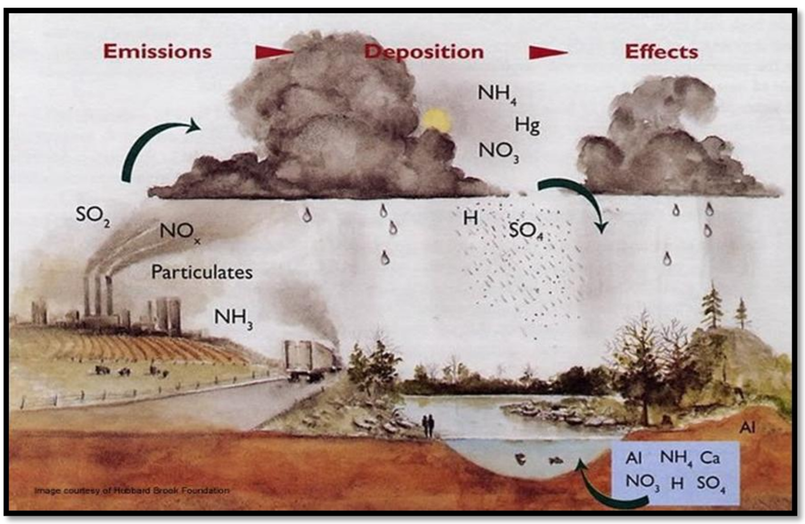


Figure 3.5: Diagram showing acid rain formation

Figure 3.7: Aesthetic damage of acid rain

Figure 3.6: Forest damage of acid

rain

Mobility of SO2

SO_2 and the pollutants formed from SO_2, such as sulfate particles, can be transported over long distances and deposited far from the point of origin. This means that problems with SO_2 are not confined to areas where it is emitted.

6) **Lead** (Pb) is a metal found naturally in the environment as well as in manufactured products. The major sources of lead emissions have historically been motor vehicles (such as cars and trucks) and industrial sources. As a result of EPA's regulatory efforts to remove lead from gasoline, emissions of lead from the transportation sector dramatically declined by 95 percent between 1980 and 1999, and levels of lead in the air decreased by 94 percent between 1980 and 1999. Today, the highest levels of lead in air are usually found near lead smelters. Other stationary sources are waste incinerators, utilities, and lead-acid battery manufacturers.

Chlorofluorocarbons (CFCs)

CFCs are lowering the average concentration of ozone in the stratosphere. Since 1978, the use of CFCs in aerosol cans has been banned in the United States, Canada, and most Scandinavian countries. Aerosols are still the largest use, accounting for 25% of global CFC use (Miller 448). Spray cans, discarded or leaking refrigeration and air conditioning equipment, and the burning plastic foam products release the CFCs into the atmosphere. Depending on the type, CFCs stay in the atmosphere from 22 to 111 years. Chlorofluorocarbons move up to the stratosphere gradually over several decades. Under high energy ultra violet (UV) radiation, they break down and release chlorine atoms, which speed up the breakdown of ozone (O_3) into oxygen gas (O_2).

Chlorofluorocarbons, also known as Freons, are greenhouse gases that contribute to global warming.

Photochemical air pollution is commonly referred to as "smog". Smog, a contraction of the words smoke and fog, has been caused throughout recorded history by water condensing on smoke particles, usually from burning coal. With the introduction of petroleum to replace coal economies in countries, photochemical smog has become predominant in many cities, which are located in sunny, warm, and dry climates with many motor vehicles. The worst episodes of photochemical smog tend to occur in summer.

Relationship between ppm and mg/L for gases

$$mg/m^3 = (ppm \times MW \times 273 \times P) / (T \times 22.4)$$

MW = molecular weight (in grams/mole)

T = temperature (ºKelvin) = 273 + ºC

P = Pressure (atm.) = mm Hg / 760

Atomic Weight (grams/mole): O = 16 N = 14 H = 1 S = 32 C = 12

Example: Riyadh's air quality standard for nitrogen dioxide (NO_2) is 470 µg/m^3 (at a temperature of 25 ºC and 760 mm Hg of pressure). Express the concentration in ppm.

Solution: Molecular weight of nitrogen dioxide (NO_2) = 14 + (2x16) = 46

$0.470 = [ppm \times 46 \times 273 \times (760/760)] / [(25+273) \times 22.4]$

$[NO_2] = 0.25$ ppm

Classification of Air Pollutants

- Natural: volcanoes, fires, oceans, soils, plants and microbes.
- Anthropogenic: arson fires, combustion-type engines, construction/destruction, chemical processes, mining and agriculture.

Air pollutants also are classified (according to the source) as:

A- Primary pollutants are those that are emitted directly into the atmosphere from an identifiable source, i.e. carbon monoxide and sulfur dioxide.

B- Secondary pollutants are those that are produced in the atmosphere by chemical and physical processes from primary pollutants and natural constituents. For example, ozone is produced by hydrocarbons and oxides of nitrogen (both of which may be produced by car emissions) and sunlight.

Indoor Air Pollution

It is usually thought of air pollution as being an outdoors event, but the air in houses or offices could also be polluted. Sources of indoor pollution include:

- Biological contaminants like mold and pollen
- Tobacco smoke
- Household products and pesticides
- Gases such as radon and carbon monoxide
- Materials used in the building such as asbestos, formaldehyde and lead

Some pollutants can cause diseases that show up much later, such as respiratory diseases or cancer. Making sure that your building is well-ventilated and eliminating pollutants can improve the quality of your indoor air.

Cooking and heating with solid fuels on open fires or traditional stoves results in high levels of indoor air pollution. Indoor smoke contains a range of health-damaging pollutants, such as small particles and carbon monoxide, and particulate pollution levels may be 20 times higher than accepted guideline values.

According to The world health report 2002 indoor air pollution is responsible for 2.7% of the global burden of disease.

Lack of ventilation indoors concentrates air pollution where people often spend the majority of their time. Radon (Rn) gas, a carcinogen, is exuded from the Earth in certain

locations and trapped inside houses. Building materials including carpeting and plywood emit formaldehyde (H_2CO) gas. Paint and solvents give off volatile organic compounds (VOCs) as they dry. Lead paint can degenerate into dust and be inhaled. Intentional air pollution is introduced with the use of air fresheners, incense, and other scented items. Controlled wood fires in stoves and fireplaces can add significant amounts of smoke particulates into the air, inside and out. Indoor pollution fatalities may be caused by using pesticides and other chemical sprays indoors without proper ventilation.

Radon

Radon cannot be seen and has no smell or taste, but it may be a problem at homes. Radon comes from the natural breakdown of uranium in soil, rock and water. It is the second leading cause of lung cancer in the United States.

Radon can enter homes and buildings through cracks in floors, walls or foundations. Radon can also be in water supplies, especially well water. Testing is the only way to know if indoor areas have elevated radon levels. Reduction systems can bring the amount of radon down to a safe level and the cost depends on the size and design of building.

Air Quality Measurement

Number of methods are used to measure air quality, including permanent monitoring stations in communities, mobile instrumentation (e.g. on a truck or airplane), and industrial stack monitoring.

These monitoring stations measure the presence of contaminants in the air, such as carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), particulate matter (PM2.5 and PM10), sulphur dioxide (SO_2), and hydrogen sulphide (H_2S).

Air Quality Standards

Emissions standards are requirements that set specific limits to the amount of pollutants that can be released into the environment. Many emissions standards focus on regulating pollutants released by automobiles (motor cars) and other powered vehicles but they can also regulate emissions from industry, power plants, small equipment such as lawn mowers and diesel generators.

Air Pollutants Control Devices

The following items are commonly used as pollution control devices by industry or transportation devices. They can either destroy contaminants or remove them from an exhaust stream before it is emitted into the atmosphere.

- **Particulate control** (Figure 3.8)
  - Mechanical collectors (dust cyclones, multicyclones)
  - Electrostatic precipitators An electrostatic precipitator (ESP), or electrostatic air cleaner, is a particulate collection device that removes particles from a flowing gas (such as air) using the force of an induced electrostatic charge. Electrostatic precipitators can easily remove fine particulate matter such as dust and smoke from the air stream.
  - Baghouses Designed to handle heavy dust loads, a dust collector consists of a blower, dust filter, a filter-cleaning system, and a dust receptacle or dust removal system (distinguished from air cleaners which utilize disposable filters to remove the dust).

- Particulate scrubbers Wet scrubber is a form of pollution control technology. The term describes a variety of devices that use pollutants from a furnace flue gas or from other gas streams. In a wet scrubber, the polluted gas stream is brought into contact with the scrubbing liquid, by spraying it with the liquid, by forcing it through a pool of liquid, or by some other contact method, so as to remove the pollutants.

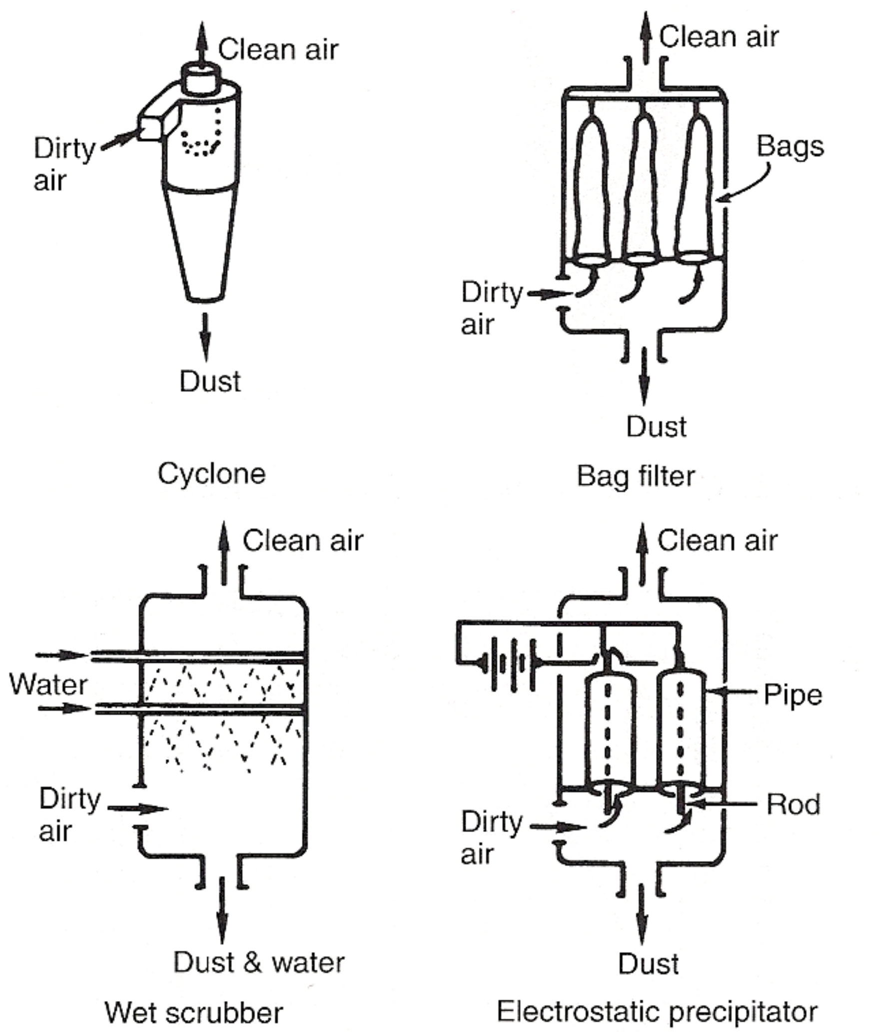


Figure 3.8**:** Four methods of controlling (trapping) particulate matter from stationary sources. (adapted from Ruth & Robin, Environmental Engineering, Fourth edition, 2003)

In general, control of pollutants that are primary in nature, such as SO_2, NO_2, CO, and Pb, is easier than control of pollutants that are either entirely secondary (O_3) or have a significant secondary component ($PM_{2.5}$). Primary pollutants may be controlled at the source. For example, SO_2 is controlled by the use of scrubbers, which are industrial devices that remove SO_2 from the exhaust gases from power plants. SO_2 emissions are also reduced by the use of low-sulfur coal or other fuels, such as natural gas, that contain lower amounts of sulfur. NO_2 from industrial sources also may be minimized by scrubbing. NO_2 from cars, as well as CO, are controlled by the use of catalytic converters, engine design modifications, and the use of cleaner burning grades of gasoline. Lead emissions have been reduced significantly since the introduction of lead-free gasoline.

Ozone and particulate matter are two of the most difficult pollutants to control. Reduction of oxides of nitrogen emissions, together with a reduction of VOC emissions is the primary control strategy for minimizing ozone concentrations. Because a large portion of PM 2.5 is secondary in nature, its control is achieved by control of SO_2, NO_2 , and VOC (which are the precursors of sulfates, nitrates, and carbon-containing particulates).

Greenhouse Effect

The **greenhouse effect** is the heating of the surface of a planet or moon due to the presence of an atmosphere containing gases (e.g. water vapor, carbon dioxide, nitrous oxide, and methane) that absorb and emit infrared radiation. Thus, greenhouse gases trap heat within the surface-troposphere system. This mechanism is fundamentally different from that of an actual greenhouse, which works by isolating warm air inside the structure so that heat is not lost by convection. The greenhouse effect was discovered by Joseph Fourier in 1824, first reliably experimented on by John Tyndall in 1858, and first reported quantitatively by Svante Arrhenius in 1896.

In the absence of the greenhouse effect and an atmosphere, the Earth's average surface temperature of 14 °C (57 °F) could be as low as −18 °C (−0.4 °F), the black body temperature of the Earth.

Human activities since the start of the industrial era around 1750 have increased the levels of greenhouse gases in the atmosphere.

Greenhouse gases in the atmosphere behave much like the glass panes in a greenhouse. Sunlight enters the Earth's atmosphere, passing through the blanket of greenhouse gases. As it reaches the Earth's surface, land, water, and biosphere absorb the sunlight's energy. Once absorbed, this energy is sent back into the atmosphere. Some of the energy passes back into space, but much of it remains trapped in the atmosphere by the greenhouse gases, causing our world to heat up (Figure 3.9). But if the greenhouse effect becomes stronger, it could make the Earth warmer than usual. Even a little extra warming may cause problems for humans, plants, and animals.

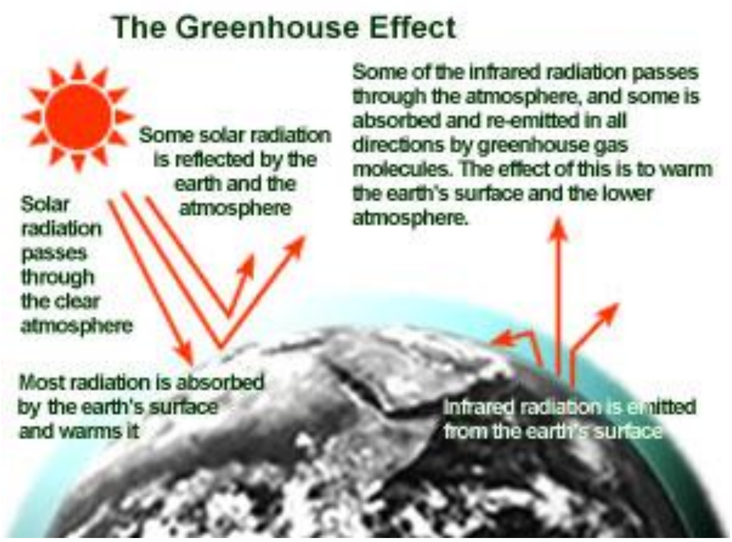


Figure 3.9**:** A schematic representation of the exchanges of energy between outer space, the Earth's atmosphere, and the Earth's surface. The ability of the atmosphere to capture and recycle energy emitted by the Earth surface is the defining characteristic of the greenhouse effect.

Global warming

Global warming is a major international problem caused mostly by human actions. It is considered a consequence of air pollution.

Global warming is the increase in the average temperature of the Earth's near-surface air and oceans since the mid-20th century and its projected continuation. Global surface temperature increased 0.74 ± 0.18 °C during the last century. Increase in global temperature caused by increasing concentrations of greenhouse gases resulting from human activity such as fossil fuel burning and deforestation referred to as anthropogenic global warming (AGW).

An increase in global temperature will cause sea levels to rise and will change the amount and pattern of precipitation, probably including expansion of subtropical deserts. The continuing retreat of glaciers, permafrost and sea ice is expected, with warming being strongest in the Arctic. Other likely effects include increases in the intensity of extreme weather events, species extinctions, and changes in agricultural yields.

Global warming is a result of greenhouse gas emissions such as carbon dioxide, methane and nitrous oxide. Because global warming has become a huge issue, greenhouse gases as air pollutants are usually discussed separately from air pollution.

Air Quality Index (AQI)

The Air Quality Index (AQI) is a number used by government agencies to characterize the quality of the air at a given location. As the AQI increases, an increasingly large percentage of the population is likely to experience increasingly severe adverse health effects.

To compute the AQI requires an air pollutant concentration from a monitor or model. The function used to convert from air pollutant concentration to AQI varies by pollutant, and is different in different countries. Air quality index values are divided into ranges,

and each range is assigned a descriptor and a color code. Standardized public health advisories are associated with each AQI range.

The AQI is an index for reporting daily air quality. It the degree of how clean or polluted air is, and what associated health concerns are present. The AQI focuses on health effects that can happen within a few hours or days after breathing polluted air.

EPA uses the AQI for five major air pollutants regulated by the Clean Air Act: ground-level ozone, particulate matter, carbon monoxide, sulfur dioxide, and nitrogen dioxide. For each of these pollutants, EPA has established national air quality standards to protect against harmful health effects. The higher the AQI value is, the greater the level of air pollution and the greater the health danger.

Environmental agencies encourage members of the public to take public transportation to work from home when AQI levels are high.

AQI Breakpoint Definitions

(Source: http://www.tceq.state.tx.us/cgi-bin/compliance/monops/aqi_rpt.pl)

AQI Range	1-hr Ozone (ppm)	8-hr Ozone (ppm)	8-hr Carbon Monoxide (ppm)	24-hr Sulfur Dioxide (ppm)	24-hr PM-10 (ug/m^3)	24-hr PM-2.5 (ug/m^3)
0 – 50	Not Defined	0 - 0.059	0 - 4.4	0 - 0.034	0 – 54	0 - 15.4
51 - 100	Not Defined	0.06 - 0.075	4.5 - 9.4	0.035 - 0.144	55 - 154	15.5 - 40.4
101 - 150	0.125 - 0.164	0.076 - 0.095	9.5 - 12.4	0.145 - 0.224	155 - 254	40.5 - 65.4
151 - 200	0.165 - 0.204	0.096 - 0.115	12.5 - 15.4	0.225 - 0.304	255 - 354	65.5 - 150.4
201 - 300	0.205 - 0.404	0.116 - 0.374	15.5 - 30.4	0.305 - 0.604	355 - 424	150.5 - 250.4
301 - 400	0.405 - 0.504	Not Defined	30.5 - 40.4	0.605 - 0.804	425 - 504	250.5 - 350.4

401 - 500	0.505 - 0.604	Not Defined	40.5 - 50.4	0.805 - 1.004	505 - 604	350.5 - 500.4
500	Not Defined	Not Defined	Not Defined	Not Defined	605 - 4999	500.5 - 999.9

AQI Values and Air Quality Descriptors	
AQI	**Descriptor**
0 – 50	Good
51 – 100	Moderate
101 – 150	Unhealthy for Sensitive Groups
151 – 200	Unhealthy
201 – 300	Very Unhealthy
301 – 400	Hazardous
500	Hazardous

Example on AQI:

Suppose on a given day the following maximum concentrations are measured:

24-hr SO_2	0.25 ppm
24-hr PM-10	425 ug/m^3
8-hr O_3	0.25 ppm
8-hr CO	8 ppm
4-hr O_3	0.42 ppm

For that day's air quality:

1) Determine the Air Quality Index, and
2) Indicate the descriptor that would be used to characterize the day's air quality.

Solution:

24-hr SO_2	0.25 ppm	151-200
24-hr PM-10	425 ug/m^3	301
8-hr O_3	0.25 ppm	201-300
8-hr CO	8 ppm	51-100
4-hr O_3	0.42 ppm	Not defined

AQI = 301

Descriptor = Hazardous

GE 302 - Industry and the Environment

Chapter IV

Solid Waste Engineering and

Hazardous Waste Management

(Review Chapters 13 and 14 of the textbook for more information)

TABLE OF CONTENTS

I - Municipal Solid Waste (MSW)

Definition

MSW, also called urban solid waste or refuse, is a waste type that includes predominantly household waste (domestic waste) with sometimes added commercial/industrial wastes collected by a municipality within a given area. MSW is in either solid or semisolid form and generally exclude industrial hazardous wastes.

Main Categories of MSW

1- Biodegradable waste: food and kitchen waste, green waste (garden & park wastes with high nitrogen content) and paper.

2- Recyclable material: paper, glass, bottles, cans, metals, certain plastics, etc.

3- Inert waste: construction and demolition waste, dirt, rocks and debris.

4- Composite wastes: waste clothing and waste plastics such as toys.

5- Domestic hazardous waste & toxic waste: medication, e-waste, paints, chemicals, light bulbs, fluorescent tubes, spray cans, fertilizer and pesticide containers, batteries, shoe polish, etc.

Factors Affecting the Production Rate

1- Life Style and Economic Conditions

2- Habits of the People

3- Environmental Awareness of the Society

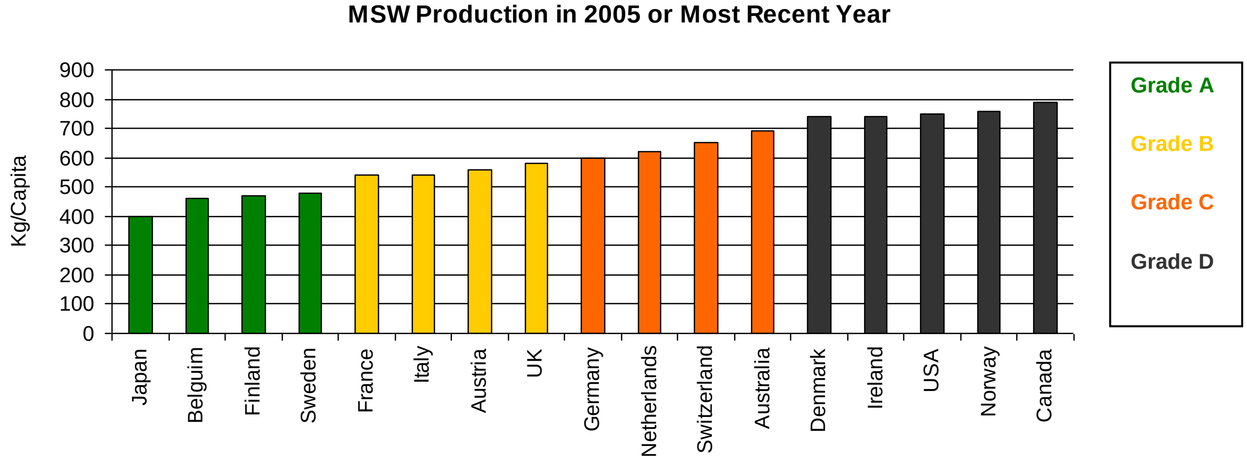
4- Geographical Location

5- Season of the Year

6- MSW Collection Frequency

7- Availability of Recycling Programs

8- Existence of Environmental Protection Acts



Source: The Conference Board of Canada
(http://www.conferenceboard.ca/HCP/Details/Environment/municipal-waste-generation.aspx) Dec 4, '09

MSW Statistics of the City of Riyadh (1427-1428H / 2006-2007G):

- Average Daily MSW reaching Al-Solay Landfill = 12,000 tons (1600 compressions); of which 55% are domestic and the rest is inert and industrial waste
- Biodegradable wastes are approximately 51% of the total domestic solid waste
- Paper and cartoon wastes are approximately 20% of the total domestic solid waste
- Number of scrap cars = 7,000 annually
- Cost of cleaning the city = 15 million SR monthly
- MSW production rate = (1-2) kg/capita/day; i.e. (360-720) kg/capita/year
- Average domestic solid waste production rate = (0.5-1) kg/capita/day

Waste Production Quantities (Tons) in Saudi Arabia (Environment and Development Magazine, 1998)

City	Quantity
Riyadh	**1,514,000**
Jeddah	**971,000**
Mecca	**697,000**
Dammam	**501,000**
Amadenah	**360,000**
Taif	**338,000**
Buraidah	**272,000**
Hofuf	**224,000**
Tabuk	**216,000**
Jizan	**180,000**
Total	**5,273,000**

Recycling and Treatment of Municipal Solid Waste (MSW)

a. Recyclable Materials and Their Re-use

1- Materials that are recyclable and may be re-used include: paper, aluminum, iron, plastic, glass and organic wastes (food waste, trees' leaves, plants and sludge)

2- After separating the MSW components, some of them can be directly recycled to produce the same original product; for example used paper and clothes. Other components can be used as raw material in industry to produce the same original product or another different product; for example glass bottles may be recycled into glass, compute chips, etc.

b. Types of Treatment of MSWs

MSWs can be treated to produce **energy** and **compost**; the latter being a combination of decomposed plant and animal materials and other organic materials that are recycled into a rich black soil.

b.1) Biological Treatment

- Aerobic decomposition of organic materials is largely used to produce compost that can enrich and improve soil properties for agricultural use. The process of

composting is simple and can be practiced by individuals in their homes, farmers on their land, and industrially by industries and cities.

- Anaerobic decomposition of organic materials that produces gases used for energy production.

b.2) Thermal Treatment

- MSW Combustion (Incineration) with Energy Recovery
    - MSW combustion produces flue gases with high temperature, and the thermal energy can be used to raise steam to drive a turbo-generator to produce electricity. In a modern waste-to-energy facility, MSW combustion and energy recovery are accomplished in an integrated design. Figure xx shows the basic process of a MSW combustion facility with integral heat recovery.

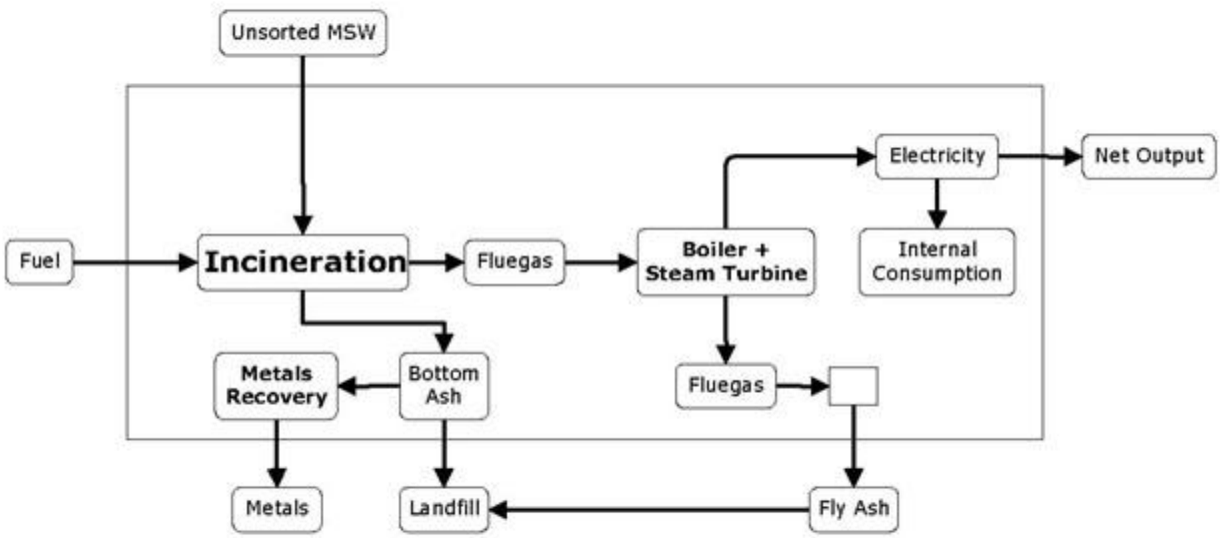


Figure 4.1: Basic Processes of a MSW Combustion Facility (extracted from the textbook)

-
    - MSW combustion typically reduces the volume of wastes by 90%. MSW combustion facilities are considered primarily as waste management facilities rather than renewable energy facilities.

- Thermal Decomposition of MSWs

- It is done anaerobically (in the absence of air); to produce oils and tar that can be used in paving roads.

- MSWs Gasification
    - Gasification is another thermal treatment option for MSW to recover energy from the organic portions of the wastes. The gasification process turns carbon-based substances into energy-rich fuel by heating under controlled conditions (burning in limited amounts of oxygen) to produce a syngas which is the mixture of carbon monoxide and hydrogen. The produced gas is combustible; hence can be used to produce energy.
    - Pretreatment of MSW is required t to ensure better performance of the gasification process, this includes: separation of inorganic ingredients, and controlling the size and moisture of feedstock.

Environmental & Economic Gains of Recycling

1- Reducing the amount of wastes that are required to be gotten rid of. This, subsequently, limits environmental pollution.

2- Reducing the overuse of natural resources. For example, recycling paper and wood reduces forest overharvesting. Likewise, recycling some metals; such as iron and aluminum, prolongs the duration of using their reserves.

3- Saving energy consumed in manufacturing processes. For example; producing aluminum from aluminum wastes requires 20% less energy than if it is produced from raw aluminum.

4- Reducing importing raw materials

Other examples that show the importance of recycling:

One recycled tin can would save enough energy to power a television for 3 hours.

One recycled glass bottle would save enough energy to power a computer for 25 minutes.

One recycled plastic bottle would save enough energy to power a 60-watt light bulb for 3 hours.

70% less energy is required to recycle paper compared with making it from raw materials.

Management of Municipal Solid Waste

To get rid of MSWs, they pass through several stages starting from their collection at the production source points all the way up to their final destination at the treatment facilities. The different processes are summarized as follows:

1- Collection and Transfer of Wastes

The costs of colleting and transferring MSWs are approximately 50% of the total costs for waste management. Collection System Types include:

a) Hauled Container System (HCS)

Container is moved to disposal site (commercial, construction, institutions)

One driver and frequent trips

b) Stationary Container System (SCS)

Container remains at site (residential and commercial)

2- Separation of Wastes

2.1 Separation at Source (manual)

- Curbside, where the producer puts the MSWs by the road for collection vehicles to pickup.

- Drop-off Centers and Buy-Back Centers, where these centers have large containers for different waste types (plastics, cans, glass, newsprint, rubber, etc.).

- Buy-Back Centers pay back money to the waste producer in return for the latter delivering the waste to the center.
- Drop-Off Centers are located usually in marketplaces, by charity organizations or near grocery stores.

2.2 Separation at Materials Recovery Facility (MRF)

- Processing of separated materials - clean MRF (baling, crushing)
- Separation of commingled MSW - dirty MRF

- Improving quality of recovered material (cleaning, separation of glass/plastics, contaminant removal).

3- Separation and Processing Stations

These stations are equipped with systems for separating the components of MSWs, pressing them into smaller volumes and cutting them into smaller units to facilitate their processing. The stations have units for the biological and/or thermal treatment of the wastes.

The main unit processes that take place in these stations are:

a) Compaction/Densification

- Reducing the size of wastes and blending constituents lead to more uniform material for processing. Glass crushers, wood grinders, tube grinders and hammer mills are used for these purposes.
- Screening of constituents using rotary screen, vibrating screen and disc screens that are useful in separating glass, aluminum cans and cardboards. The opening size is adjustable based on desired separation. Also useful in removing heavy/light components and under/over-sized material.

b) Mechanical Separation

- Ferrous metal - most successful, magnetism

1. Non-ferrous – flotation

c) Air Classification - major MSW unit process (second to magnetic) - current of air is used to effect material separation based on density, viscous drag
    i. Separation of light organics (combustible) fraction from heavy inorganics

4- Transfer Stations

These stations receive bales of compressed materials from MSWs to be transferred through large trucks that deliver them either to the final processing stations or to the separation and processing stations especially if the former are too far away.

5- Disposing the Waste and Residual Components of the Separation and Processing Stations

a) Traditional Methods

   a. Disposal out of urban areas
   b. Incineration in remote areas
   c. Disposal in seas and oceans
   d. Mixing the bio-waste with soils

   These methods have negative impacts on the environment leading to environmental pollution of air, water and soil. They also provide breeding grounds for insects, rodents and other disease-carriers.

b) Incineration (high capital cost and causes environmental pollution problems - Waste reduction is immediate, no long term residency required)

c) Sanitary Landfills – they are simply engineered excavations in the ground, the purpose of which is to get rid of the waste in an environmentally clean way.

Sanitary Landfill (selection, leachate, gasses)

The building block of a sanitary landfill is the daily cells. All the solid wastes received are spreaded and compressed in layers within a confined area. At the end of each working day, or more frequently, it is covered completely with a thin, continuous layer of soil, which is then also compacted. The compacted waste and soil cover constitute a cell. Figure 4-2 shows a schematic cross-section in a modern landfill.

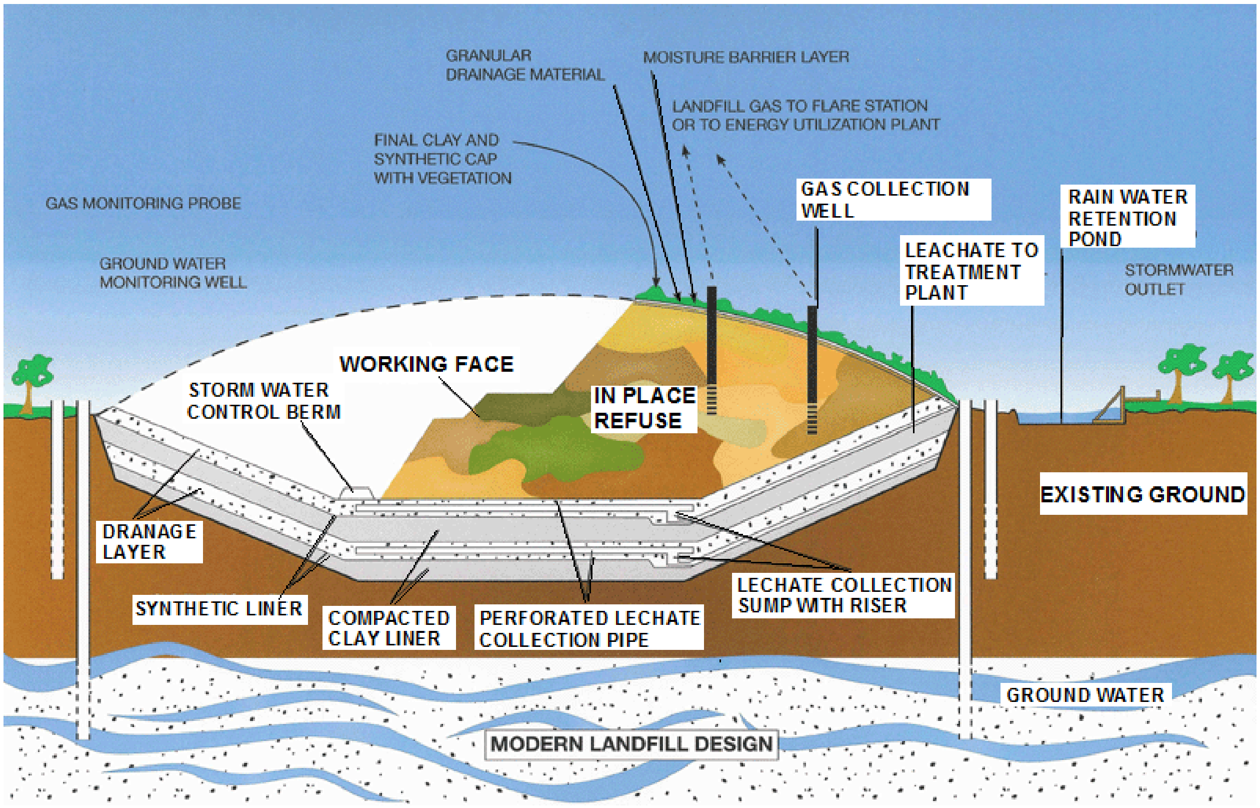


Figure 4.2: Labeled cross-section of an engineered landfill.

Different reactions occur to the disposed wastes in a landfill: these are chemical, physical and biological in nature and happen to both organic and inorganic compounds. The following text describes the main outcomes of these reactions.

Leachate: Groundwater or infiltrating surface water moving through solid waste can produce leachate; a solution containing dissolved and finely suspended solid matter and microbial waste products. All landfills produce some leachate whether sanitary landfill or open dumping site. The leachate may also contain dissolved heavy metals and organic chemicals.

Produced Gases:
Gases are produced naturally when solid wastes are decomposed whether in a sanitary landfill or open dumping site. Biological activity within a landfill follows a set pattern. Landfill gas is important to consider when evaluating the effect a landfill may have on the environment. Common gases are: methane (CH_4) and carbon dioxide (CO_2). Methane can explode if not properly captured and because mineralization of ground water can occur, carbon dioxide is generated and may dissolve in ground water and forms carbonic acid.

The gases produced by decomposition of landfill wastes can be used for energy production. If the production of gases proves commercially feasible, gas recovery facilities may be installed at the landfill sites.

Sanitary Landfill Design and Design Example

For modern sanitary landfill design, geosynthetics are commonly used. Geosynthetic means the generic classification of all synthetic materials used in geotechnical applications.

Public health aspects:
In industrial landfill leachate, 32 chemicals may cause cancer; 10 may cause birth defects, and 21 may cause genetic damage. In municipal landfill leachate, 32 chemicals may cause cancer, 13 may cause birth defects, and 22 may cause genetic damage.

Example:

A city has 600,000 inhabitants. The daily MSW production rate is approximately 2 kg. Estimate the following requirements under the given conditions:

a) If the municipality has 170 vehicles for waste disposal; each has 10 m^3 capacities, estimate the number of additional vehicles required to transfer the daily generated waste to a remote landfill. Assume all vehicles have equipment that compresses the wastes to a density of 320 kg/m^3, and each vehicle makes two trips per day.
b) If the landfill area is approximately 0.5 km x 1.0 km and its average depth is 10.0 m, estimate the number of hijri years (354 days/year) that the landfill will serve. Assume the wastes layers in the landfill will be compacted to a density of 400 kg/m^3

c) If one recycling company proposed reducing the wastes by 20% through recycling, estimate the number of years the landfill will serve in this case.

Solution:

a- Exact No. of vehicles required = (600,000 x 2) / (10 x 320 x 2) = 187.5 or 188 vehicles

   Use 12 vehicles standby, No. of vehicles required = 188 + 12 = 200 vehicles

   Number of additional vehicles required = 200 – 170 = 30 vehicles

b- Capacity of the landfill = 500 x 1000 x 10 x 400 = 2 x 10^9 kg

   Daily MSW production rate of the city = 600,000 x 2 = 1.2 x 10^6 kg

Number of hijri years that the landfill will serve = $2 \times 10^9 / (1.2 \times 10^6 \times 354)$= 4.71 years

c- Number of hijri years that the landfill will serve = $2 \times 10^9 / (0.8 \times 1.2 \times 10^6 \times 354)$= 5.89 years

Actions for Better Waste Management

1- Reduce, Reuse and Recycle (the three-Rs)

Source reduction, often called waste prevention, means consuming and throwing away less. Source reduction includes purchasing durable, long-lasting goods and seeking products and packaging that are as free of toxics as possible. We all can use the material again as its original or subsidiary form.

2- Composting

3- Combustion and Incineration

4- Sanitary Landfills

II - Hazardous Wastes

Definition

Hazardous waste is waste that is dangerous or potentially harmful to our health or the environment. Hazardous wastes can be liquids, solids, gases, or sludge. They can be discarded commercial products, like cleaning fluids or pesticides, or the by-products of manufacturing processes. They may be radioactive, corrosive, combustible, exploding and toxic compounds that require special care during their handling, transfer or storage.

Picture: Hazardous wastes

Sources

1- Wastes of workshops, gas stations, auto-service units: they include oils, solvents, petrochemicals, rubber tires, batteries, etc.

2- Wastes of laboratories (universities, research centers, schools, etc.), dry cleaning facilities, film development stores, etc.

3- Wastes of power plants, mining, smelters and other industrial activities.

4- Wastes of medical facilities (medical labs, hospitals, clinics, etc.) that have chemical, biological and radioactive characteristics.

Characteristics of Hazardous Wastes

1. Flammable

- Liquid containing less than 24% alcohol by volume and has a flash point less than 60^0 C.

- Not a liquid and is capable, under std. temperature & pressure of causing fire through friction, absorption of moisture or spontaneous chemical changes, and when ignited burns so vigorously and persistently, thus creates hazard.

- An ignitable compressed gas.

- An oxidizer

- Examples: Waste oils, used organic solvents and PCB).

2. Corrosive (corrosive to human tissues and metals)

- A solution that has a pH less than or equal to 2 or greater than or equal to 12.5.

- A liquid that corrodes steel at a rate greater than 6.35 mm per yr at a test temperature of 55^0C)

- Examples: Strong acids, strong bases

3. Toxic

- It poses danger to human, plant, and animal health through inhalation, inhalation or surface contact.

- Examples: DDT, dioxins

<u>Example of Industrial Hazardous Wastes</u>

1. Acids (sources : petroleum & chemical industries, incinerator ash)

2. Cyanide (sources : metal & chemical industries)

3. Arsenic (sources : glass manufacturing processes, pesticides)

4. Cadmium (sources : paint & plastic industries, battery manufacturers)

5. Lead (sources : electronic industry)

6. Infectious waste (sources : hospitals, clinics)

7. Organic solvents (sources : plastic, adhesive, cosmetic industries)

8. Radioactive waste (sources : nuclear power plant)

Hazardous Waste Recycling

Many industrial hazardous wastes can be recycled safely and effectively. A hazardous waste is recycled if it is used, reused, or reclaimed. Furthermore, hazardous waste regulation makes an important distinction between materials that are used or reused without reclamation and those that must be reclaimed before reuse. A material is reclaimed if it is processed to recover a usable product, or if it is regenerated. Common hazardous waste reclamation activities involve recovery of spent solvents (e.g., recovery of acetone) or metals (e.g., recovery of lead). An example of a material that is reused without reclamation is emission control dust returned directly to a primary zinc smelting furnace.

GE 302 - Industry and the Environment

Chapter V – NOISE POLLUTION

Contents

5.1 Definition

Noise pollution (or environmental noise) is displeasing human-, animal- or machine-produced sound that disrupts the activity or balance of human or animal life.

The unwanted sound is called noise.

5.2 Sound Waves and Properties

Sound is produced by waves traveling in air, and just like waves in the ocean, they have height and, spacing. The height is a measure of the power of the sound, and is known as amplitude or volume. The spacing, peak to peak, is known as frequency or pitch. It is an indicator of how the sound will seem to our ears, from a low rumble to a high squeal.

Sounds are pressure waves reaching our hearing apparatus by the movement of surrounding air molecules.

5.3 Levels and the Decibel

Decibel, dB, it is the unit used to measure the loudness of sound. It is one tenth of a bel (named for A. G. Bell), but the larger unit is rarely used.

Decibel, dB, sound unit : a logarithmic unit of sound intensity; 10 times the logarithm of the ratio of the sound intensity to some reference intensity

given by dB = 10 $\log_{10}$ (I / I_R), where I is measured intensity and I_R is reference intensity.

The loudest sounds that can be tolerated by the human ear are about 120 dB. The level of normal conversation is about 50 to 60 dB. The decibel is also used to measure certain other quantities, such as power loss in telephone lines.

Noise intensity is measured in decibel units. The decibel scale is logarithmic; each 10-decibel increase represents a tenfold increase in noise intensity. Human perception of loudness also conforms to a logarithmic scale; a 10-decibel increase is perceived as roughly a doubling of loudness. Thus, 30 decibels is 10 times more intense than 20 decibels and sounds twice as loud; 40 decibels is 100 times more intense than 20 and sounds 4 times as loud; 80 decibels is 1 million times more intense than 20 and sounds 64 times as loud. Distance diminishes the effective decibel level reaching the ear. Thus, moderate auto traffic at a distance of 100 ft (30 m) rates about 50 decibels. To a driver with a car window open or a pedestrian on the sidewalk, the same traffic rates about 70 decibels; that is, it sounds 4 times louder. At a distance of 2,000 ft (600 m), the noise of a jet takeoff reaches about 110 decibels—approximately the same as an automobile horn only 3 ft (1 m) away.

Table 1. Sound intensity levels.

Decibel Level (dB)	Source
140	threshold of pain: gunshot, siren at 100 feet
135	jet take off, amplified music
120	chain saw, jack hammer, snowmobile
100	tractor, farm equipment, power saw
90	OSHA limit - hearing damage if excessive exposure to noise levels above 90 dB
85	inside acoustically insulated tractor cab
75	average radio, vacuum cleaner

60	normal conversation
45	rustling leaves, soft music
30	Whisper
15	threshold of hearing
0	acute threshold of hearing - weakest sound

Sound is measured by sound level meter.

The ear of the young, audiometrically healthy, adult male respond to sound waves in the frequency range of 20 to 16,000 Hz. Young children and women often have the capacity to respond to frequencies up 20,000 Hz. The speech zone lies in the range from 2000 to 5000 Hz.

5.4 Human health effects (Environmental effects)

Subjected to 45 decibels of noise, the average person cannot sleep. At 120 decibels the ear registers pain, but hearing damage begins at a much lower level, about 85 decibels. The duration of the exposure is also important. There is evidence that among young Americans hearing sensitivity is decreasing year by year because of exposure to noise, including excessively amplified music. Apart from hearing loss, such noise can cause lack of sleep, irritability, heartburn, indigestion, ulcers, high blood pressure, and possibly heart disease. One burst of noise, as from a passing truck, is known to alter

endocrine, neurological, and cardiovascular functions in many individuals; prolonged or frequent exposure to such noise tends to make the physiological disturbances chronic. In addition, noise-induced stress causes severe tension in daily living and contributes to mental illness.

Noise health effects are both health and behavioral in nature. This unwanted sound can damage physiological and psychological health. The effects of noise can be broken into three areas:

- Physiological effects:
  - noise-induced hearing loss (Chronic exposure to noise may cause noise-induced hearing loss)
  - tinnitus
  - aural (hearing related) pain,
  - nausea
  - reduced muscular control.
  - Hypertension
- Psychological effects:
  - noise can startle (frighten)
  - annoy (make angry)
  - sleep disturbances,
  - high stress levels
  - effects negatively the annoyance, sleep interface, performance and acustic privacy, agression
- Interference with communications.

Furthermore, stress and hypertension may cause further health problems. Moreover, tinnitus can lead to forgetfulness, severe depression and at times panic attacks.

Noise also makes species communicate louder, which is called Lombard vocal response.

5.5 Noise Sources and Noise Control

5.5.1 SOURCES:

Noise pollution, human-made noise harmful to health or welfare. Transportation vehicles are the worst offenders, with aircraft, railroad stock, trucks, buses, automobiles, and motorcycles all producing excessive noise. Construction equipment, e.g., jackhammers and bulldozers, also produce substantial noise pollution.

The source of most outdoor noise worldwide is transportation systems, including motor vehicle noise, aircraft noise and rail noise. Poor urban planning may give rise to noise pollution, since side-by-side industrial and residential buildings can result in noise pollution in the residential area.

Other sources of indoor and outdoor noise pollution are car alarms, emergency service sirens, office equipment, factory machinery, construction work, grounds keeping equipment, barking dogs, appliances, power tools, lighting hum, audio entertainment systems, loudspeakers, and noisy people.

5.5.2 MITIGATION AND CONTROL OF NOISE:

Technology to mitigate or remove noise can be applied as follows:

There are a variety of strategies for mitigating roadway noise including: use of noise barriers, limitation of vehicle speeds, alteration of roadway surface texture, limitation of heavy vehicles, use of traffic controls that smooth vehicle flow to reduce braking and acceleration, and tire design. An important factor in applying these strategies is a computer model for roadway noise, that is capable of addressing local topography, meteorology, traffic operations and hypothetical mitigation. Costs of building-in mitigation can be modest, provided these solutions are sought in the planning stage of a roadway project.

The *sound tube* in Melbourne, Australia, designed to reduce roadway noise without detracting from the area's aesthetics.

Aircraft noise can be reduced to some extent by design of quieter jet engines, which was pursued vigorously in the 1970s and 1980s. This strategy has brought limited but noticeable reduction of urban sound levels. Reconsideration of operations, such as altering flight paths and time of day runway use, has demonstrated benefits for residential populations near airports. FAA sponsored residential retrofit (insulation) programs initiated in the 1970s has also enjoyed success in reducing interior residential noise in thousands of residences across the United States.

Exposure of workers to Industrial noise has been addressed since the 1930s. Changes include redesign of industrial equipment, shock mounting assemblies and physical barriers in the workplace.

There are four basic principles of noise control:

- Sound insulation: prevent the transmission of noise by the introduction of a mass barrier. Common materials have high-density properties such as brick, concrete, metal etc.
- Sound absorption: a porous material which acts as a ‘noise sponge’ by converting the sound energy into heat within the material. Common sound absorption materials include open cell foams and fiberglass
- Vibration damping: applicable for large vibrating surfaces. The damping mechanism works by extracting the vibration energy from the thin sheet and dissipating it as heat. A common material is sound deadened steel.
- Vibration isolation: prevents transmission of vibration energy from a source to a receiver by introducing a flexible element or a physical break. Common vibration isolators are springs, rubber mounts, cork etc.

5.6 Allowable Noise Levels

The two factors that determine how hazardous noise is are:

- Intensity (Loudness) measured in dBA
- Time of Exposure measured in Hours and Minutes

The louder the noise, the more hazardous it is. Also, the longer the exposure time, the more hazardous the noise is.

A "Noise Dose" combines both loudness and time and is a convenient way of describing the relative hazard of the noise.

Table 2. Permissible noise exposure scale*

Duration - hours per day	Sound level (dBA)
8	90
4	95
2	100
1	105
1/2	110
1/4 or less	115

* Based on OSHA Noise Standard.

GE 302 - Industry and the Environment

Chapter VI

Environmental Ethics

and

Fundamentals of Environmental Impact Assessment (EIA)

(Note: Review Chapter 1 of the textbook for more information)

Resources: the information presented in this chapter were extracted primarily from the textbook, online dictionary (www.dictionary.com) and the webpage of the Global Development Research Center http://www.gdrc.org/

Ethics

Ethics (also known as **moral philosophy**) is that branch of philosophy dealing with values relating to human conduct, with respect to the rightness and wrongness of certain actions and to the goodness and badness of the motives and ends of such actions.

Codes of Ethics

A code of ethics is a set of conduct principles that guide decision making and behaviour in an organization. The purpose of the code is to provide members and other interested persons with guidelines for making ethical choices in the conduct of their work.

Examples of Some Codes of Ethics:

Codes of ethics can be established in many organizations that have different practices. The following codes are examples.

- Codes of Ethics of Professional Engineers
- Medical Codes of Ethics
- Business Codes of Ethics

Environmental Ethics

The birth of environmental ethics as a force is partly a result of concern for our own long-term survival, as well as our realization that humans are but one form of life, and that we share our earth with other forms of life (Vesilind, 1975).

The *hadeeth* (saying) of Prophet Muhammad (peace be upon him) "لا ضرر و لا ضرار" the meaning of which may be translated to " no harm and no damage" expresses the same concept since more than 1400 years.

Table 6-1 (extracted from the text book; there numbered 1-5) summarizes few points that represent a simple environmental code of ethics.

Table 6-1: An Environmental Code of Ethics

1- Use knowledge and skill for the enhancement and protection of the environment.

2- Hold paramount the health, safety and welfare of the environment.

3- Perform services only in areas of personal expertise.

4- Be honest and impartial in serving the public, your employers, your clients and the environment.

5- Issue public statement only in an objective and truthful manner.

Although these few principles seem straightforward, real-world problems offer distinct challenges. The following case explains the difficulty some may face in taking their decisions.

Case 1: To Add or Not to Add

A friend of yours has discovered that his firm is adding nitrites and nitrates to bacon to help preserve it. He also has read that these compounds are precursors to cancer-forming chemicals that are produced in the body. On the other hand, he realizes that certain disease organisms such as those that manufacture botulism toxin have been known to grow in bacon that has not been treated. He asks you whether he should:

(a) protest to his supervisors knowing he might get fired,

(b) leak the news to the press,

(c) remain silent because the risk of dying from cancer is less than the absolute certainty of dying from botulism.

Note: The addition of nitrite to bacon is approved by the Food and Drug Administration (FDA) of the USA. Nitrites and nitrates are, in and of themselves, not very toxic to adults. However, heating these compounds results in a reaction with the amines in proteins to form nitrosamine, which is a carcinogenic compound.

What is Environmental Impact Assessment (EIA)?

The International Association for Impact Assessment (IAIA) defines an environmental impact assessment as "the process of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of development proposals prior to major decisions being taken and commitments made." The purpose of the assessment is to ensure that decision makers consider the ensuing environmental impacts to decide whether to proceed with the project.

After an EIA, the precautionary and polluter pays principles may be applied to prevent, limit, or require strict liability or insurance coverage to a project, based on its likely harms. Environmental impact assessments are sometimes controversial.

This means that it is easy to identify;

1. The most environmental suitable option at an early stage.
2. The Best Practicable Environmental Option.
3. Alternative processes.

The project managers can then address these problems in order to avoid or minimize environmental impacts in conjunction with their project planning. This results in the likelihood of the project planning stages running smoother.

Examples of projects that may require EIA include: incinerators, airports, dams, subway, harbour, etc.

The Environmental Assessment is carried out by the Developer although the task is often carried out by Environmental Consultants. Environmental Assessment is carried out in order to produce an Environmental Statement. The Environmental Statement must include:

- A description of the project: location, design, scale, size etc.
- Description of significant effects.
- Mitigating measures
- A non-technical summary.

Why EIAs?

EIAs have two roles - legal and educational.

The legal one is to ensure that development projects have a minimal impact on the environment in their entire 'lifecycle'.

The educational one is to educate everyone involved - professionals and users included, of the potential environmental impacts of anything we do.

The EIA Process

Source: Adopted from "What is EIA?" by Richard Hamilton

The main steps in an EIA process are as follows:

- Preliminary activities include the selection of a coordinator for the EIA and the collection of background information. This should be undertaken as soon as a project has been identified.
- Impact identification involves a broad analysis of the impacts of project activities with a view to identifying those which are worthy of a detailed study.
- Baseline study entails the collection of detailed information and data on the condition of the project area prior to the project's implementation.
- Impact evaluation should be done whenever possible in quantitative terms and should include the working-out of potential mitigation measures. Impact evaluation cannot proceed until project alternative has been defined, but should be completed early enough to permit decisions to be made in a timely fashion.
- Assessment involves combining environmental losses and gains with economic costs and benefits to procedure a complete account to each project alternative. Cost-benefit analysis should include environmental impacts where these can be evaluated in monetary terms.
- Documentation is prepared to describe the work done in the EIA. A working document is prepared to provide clearly stated and argued recommendations for immediate action. The working document should contain a list of project alternative with comments on the environmental and economic impacts of each.
- Decision-making begins when the working document reaches the decision maker, who will either accept one of the project alternatives, request further study or reject the proposed action altogether.
- Post audits are made to determine how close to reality the EIA predictions were.