Department of Civil Engineering
College of Engineering
King Saud University

GE 302 – Industry and the Environment
Topic 1

Introduction to the Environment and Ecosystems

Course Description

- This course introduces the **impact of engineering and industrial activities** on the environment.
- The lectures cover basics of ecosystems, environmental balance, types of pollution, and types, sources, and limits of pollutants; in addition to fundamentals of Environmental Impact Assessment (EIA).
- **Pollution control technologies** and examples of pollution from various engineering and industrial sectors are also covered.
- The course also includes a group term project.

Course Learning Objectives (CLOs)

Students completing this course successfully will be able to:

1. Understand the basics of the global ecosystem and the natural cycles of its major components.
2. Understand the types of environmental pollution caused by engineering and industrial activities.
3. Realize the importance of sustainable development and maintaining environmental balance.
4. Understand the different types of pollutants, their sources, limits and the various technologies for pollution control.
5. Recognize the importance of EIA prior the development of the projects.
6. Improve their communication skills, including reading, writing, and oral presentations.

Course Description

Textbook:

- G. Tyler Miller, Scott Spoolman (2014) **Living in the Environment**, 17th edition, Cengage Learning. (Chapter: 3, 6, & 23)
- Jerry A. Nathanson, Richard A. Schneider (2014**) Basic Environmental Technology: Water Supply, Waste Management, and Pollution Control**, 6th edition, Pearson Education. (Chapter: 5, 11, 12, 13, & 14)
- Grade Distribution:

Two Mid-term Exams:	40%
Activities (field visit, quizzes, etc.):	10%
Project:	10%
Final Exam:	40%

Examinations:

1st midterm on: (**Monday 10/02/1439;** 30/10/2017)

2nd midterm on: (**Monday 23/03/1439;** 11/12/2017)

Course Schedule

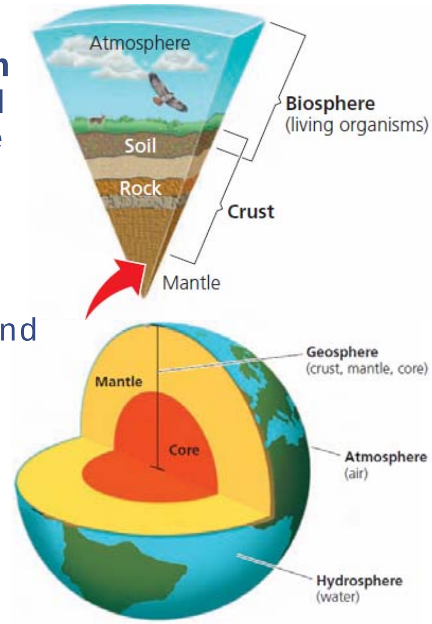
Week	Topic
1	Introduction to ecosystems
2	Hydrologic and nutrients cycle
3	The human population and its impact
4	Water pollution and control
5	Water pollution and control
6	Water pollution and control
7	Air Pollution and control
8	Air Pollution and control

Course Schedule

Week	Topic
9	Air Pollution and control
10	Municipal solid waste
11	Hazardous waste management
12	Noise pollution and control
13	Environmental impact studies and audits
14	Sustainability
15	Sustainability

Environmental components of earth

- The **earth's life-support system** consists of four main spherical systems that interact with one another
  - The atmosphere (air)
  - the hydrosphere (water)
  - the geosphere (rock, soil, and sediment)
  - the biosphere (living things)



(a) Land, air, water, and plants in Siberia

(b) Monarch butterfly and flower

(c) Endangered Siberian tiger

(d) Coral reef in Hawaii

Land, air, water, and a variety of plants and animals sustain the earth's diversity of life and human economies.

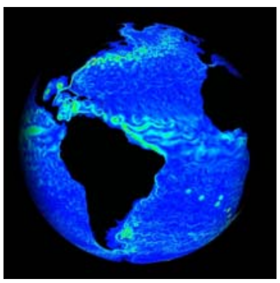
The atmosphere

- Is a thin **spherical envelope of gases** surrounding the earth's surface.
- Its inner layer, the **troposphere**, contains air that we breathe, which consists of:
  - nitrogen (78% of the total volume)
  - oxygen (21%).
  - The remaining 1% of the air includes water vapor, carbon dioxide, methane, etc. all of which are called **greenhouse gases**
- The next layer is called the **stratosphere**, Its lower portion holds enough ozone (O_3) gas to filter out about 95% of the sun's harmful **ultraviolet (UV) radiation**

9

The hydrosphere

- consists of all of the water on or near the earth's surface.
- It is found as **water vapor** in the atmosphere, **liquid water** on the surface and underground, and **ice**.
- The oceans, which cover about 71% of the globe, contain about 97% of the earth's water.



10

The geosphere

- consists of the earth's intensely hot **core**, a thick **mantle** composed mostly of rock, and a thin outer **crust**.
- Its upper portion contains **nonrenewable fossil fuels and minerals** that we use, as well as **renewable soil chemicals** (**nutrients**) that organisms need in order to live, grow, and reproduce.

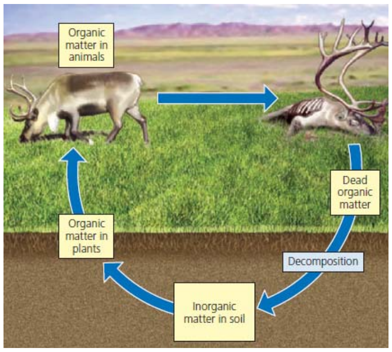
The biosphere

- consists of the parts of the atmosphere, hydrosphere, and geosphere where life is found.

11

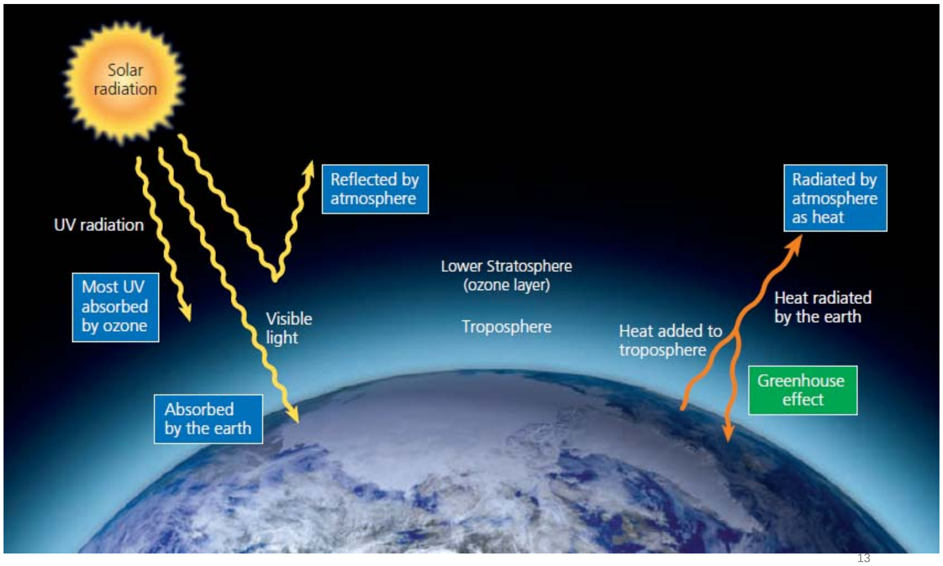
Factors Sustain the Earth's Life

1. The **one-way flow of high-quality energy** from the sun, through living things in their feeding interactions.
2. The **cycling of nutrients** (the atoms, ions, and molecules needed for survival by living organisms) through parts of the biosphere.
3. **Gravity**, which allows the planet to **hold onto its atmosphere** and helps to enable the **movement and cycling of chemicals** through air, water, soil, and organisms.



12

Interaction of solar energy with the atmosphere and earth's surface



13

Energy flow from sun to earth and within the earth's systems

- **Sun releases** tremendous amounts of **energy** into the space, only a very small amount of this energy reaches the earth.
- This energy reaches the earth in the form of **electromagnetic waves**, composed mostly of **visible light, ultraviolet (UV) radiation**, and heat (**infrared radiation**).
- Much of this **energy is absorbed or reflected back** into space by the earth's atmosphere and surface.
- The solar energy that reaches the atmosphere **lights the earth** during daytime, **warms the air**, **evaporates and cycles water** through the biosphere, and **generate winds**.
- Also, **green plant** and algae use solar energy to produce the nutrient they need through the **photosynthesis process**, and in turn, to feed the animal.

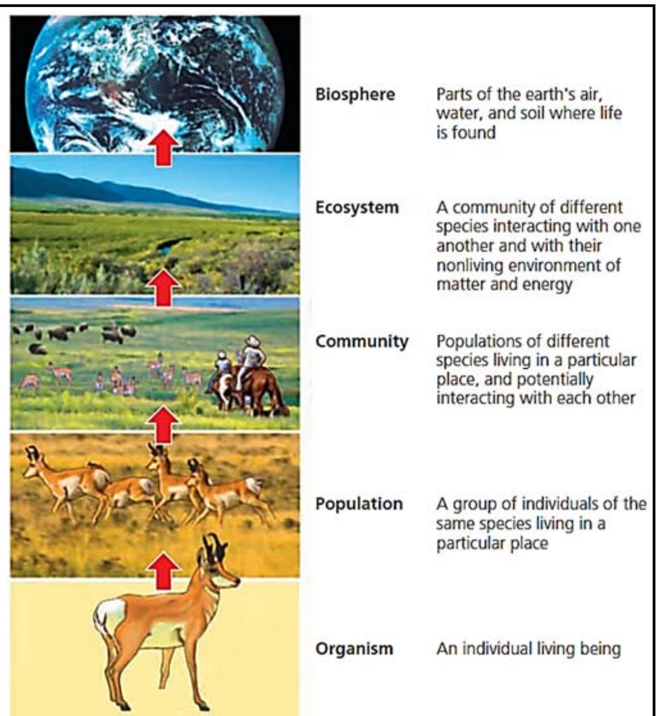
14

Energy flow from sun to earth and within the earth's systems

- The **solar radiation** reached the planet's surface, interacts with the earth's land, water, and life and is **degraded to lower-quality infrared radiation**.
- Some of the **infrared radiation** is reflected back to the lower atmosphere, where it will **interact with greenhouse gases** (water vapor, carbon dioxide, methane, etc.) and Some of it flows back into space as heat.
- When radiated heat from earth's surface interact with greenhouses gases it **warm** the lower atmosphere and the **earth's surfaces**, which is know as **greenhouse effect**.
- Without this natural greenhouse effect, the earth would be too cold to support the forms of life we find here today.

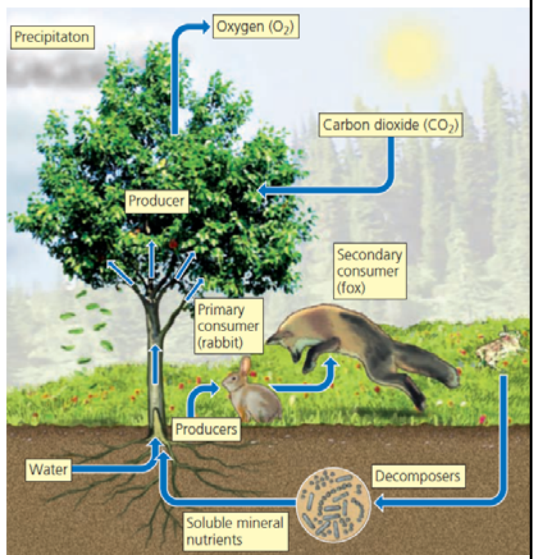
15

Ecology is the science that focuses on how organisms interact with one another and with their nonliving environment of matter and energy.



Ecosystems Have Living and Nonliving Components

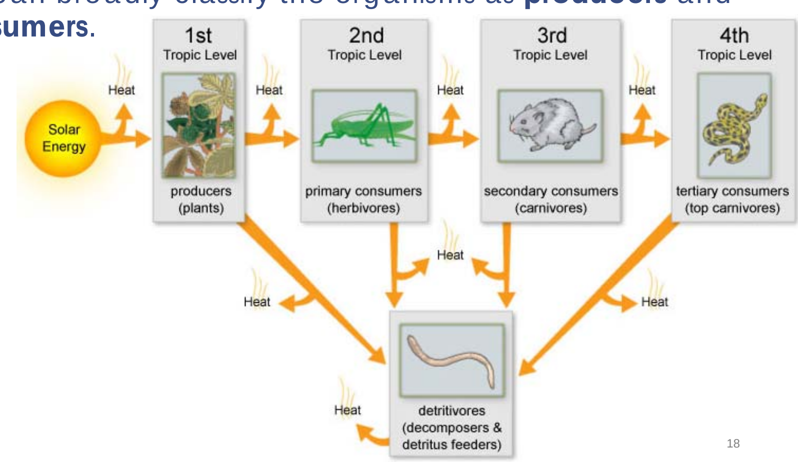
- The ecosystems are made up of living (**biotic**) and nonliving (**abiotic**) components.
- **nonliving components** are water, air, nutrients, rocks, heat, and solar energy.
- **Living components** include plants, animals, microbes, and all other organisms.



17

Trophic level

- Depending on its **source of food or nutrients**, organism in an ecosystem is assigned to a **feeding level**, or **trophic level**
- living organisms **transfer energy and nutrients** from one trophic level to another within an ecosystem
- We can broadly classify the organisms as **producers** and **consumers**.



18

- **Producers**, sometimes called **autotrophs** (self-feeders), make the nutrients they need from compounds and energy obtained from their environment.
- In a process called **photosynthesis**, plants typically capture solar energy that falls on their leaves and use it in combination with carbon dioxide and water to form organic molecules.

carbon dioxide + water + solar energy → glucose + oxygen

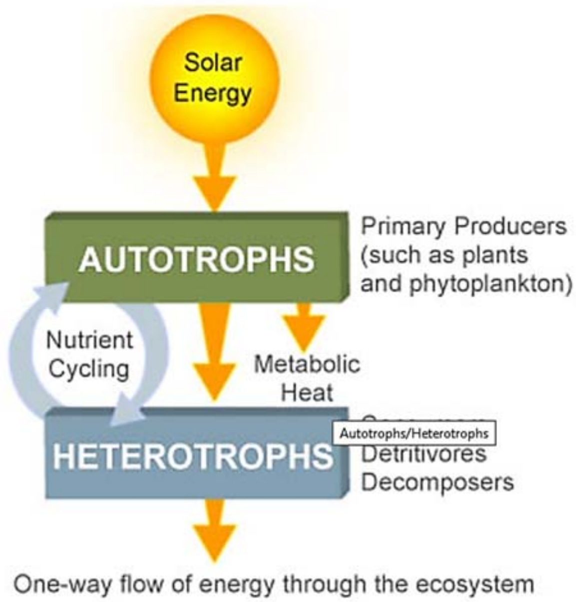
$$6\ CO_2 + 6\ H_2O + \text{solar energy} \rightarrow C_6H_{12}O_6 + 6\ O_2$$

green plants

algae and aquatic plants

- **Consumers**, or **heterotrophs**, cannot produce the nutrients they need through photosynthesis or other processes.
- Consumers obtain their energy and nutrients by feeding on other organisms (producers or other consumers).
- Types of consumers:
  - **Herbivores**, or **Primary consumers,** (plant eater), are animals that eat mostly green plants.
  - **Carnivores** (meat eaters) are animals that feed on the flesh of other animals.
    - **secondary consumers** that feed on the flesh of herbivores
    - **tertiary consumers** that feed on the flesh of other carnivores
  - **Omnivores** eat plants and other animals.
  - **Decomposers** release nutrients from the wastes or remains of plants and animals and then return those nutrients to the soil, water, and air for reuse by producers (bacteria and fungi).

- In natural ecosystems the wastes and dead bodies of organisms serve as resources for other organisms, as the nutrients that make life possible are continuously recycled
- Without decomposer, the planet would be overwhelmed with plant litter, animal wastes, dead animal bodies, and garbage.



21

Giraffe feeding on the leaves of a tree is an herbivore

lion feeding on the dead body of a giraffe is carnivores

fungus feeding on a dead tree is a decomposer

22

Aerobic & anaerobic respiration

- Consumers, and decomposers use the chemical energy stored in glucose and other organic compounds to fuel their life processes.
- This energy is released by:
  - **Aerobic respiration** which uses oxygen to convert glucose (or other organic nutrient molecules) back into carbon dioxide and water.

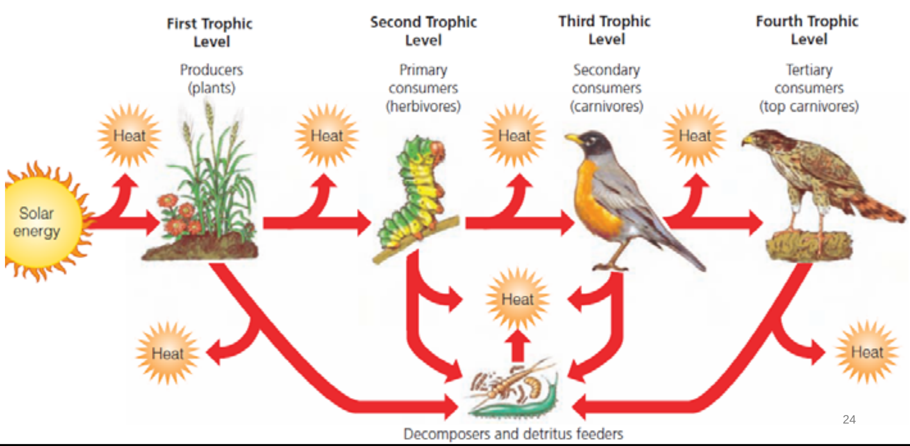
$$\text{glucose} + \text{oxygen} \longrightarrow \text{carbon dioxide} + \text{water} + \text{energy}$$

$$C_6H_{12}O_6 + 6\,O_2 \longrightarrow 6\,CO_2 + 6\,H_2O + \text{energy}$$

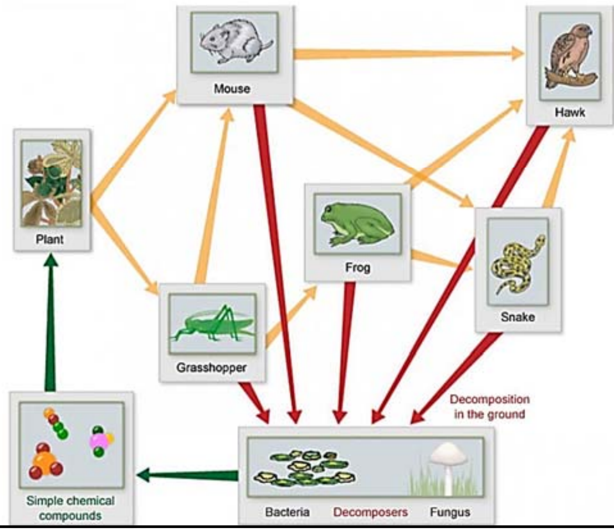
  - **Anaerobic respiration,** or **fermentation,** which breaks down organic compounds in the absence of oxygen. The end products of this process are compounds such as methane gas (CH_4), hydrogen sulfide (H_2S), etc.

Energy Flows through Ecosystems in Food Chains and Food Webs

- The chemical energy stored as nutrients in the bodies and wastes of organisms flows through ecosystems from one trophic (feeding) level to another.
- **Food chain** is a sequence of organisms, each of which serves as a source of food or energy for the next.

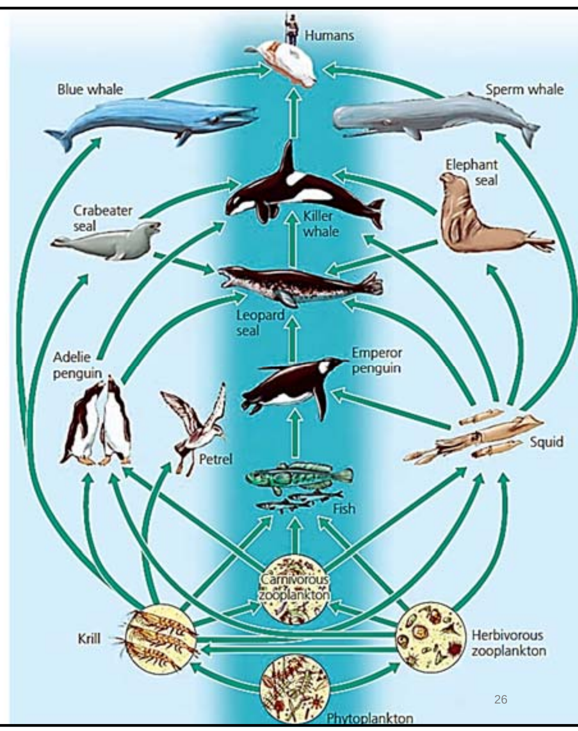


- In natural ecosystems, most consumers feed on more than one type of organism, and most organisms are eaten or decomposed by more than one type of consumer.
- Organisms in most ecosystems form a complex network of interconnected food chains called a **food web**.

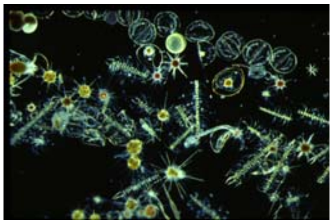


25

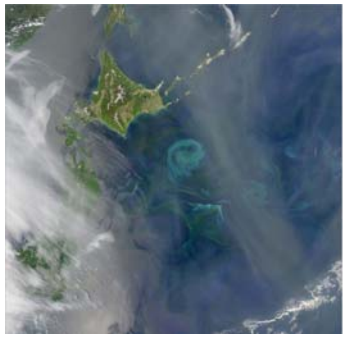
This diagram illustrates a greatly simplified food web in the southern hemisphere. The shaded middle area shows a simple food chain. Its participants interact in feeding relationships to form the more complex food web shown here.

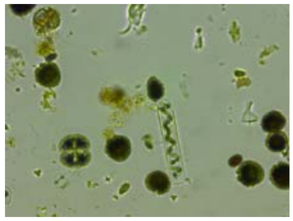


26



Marine Phytoplankton





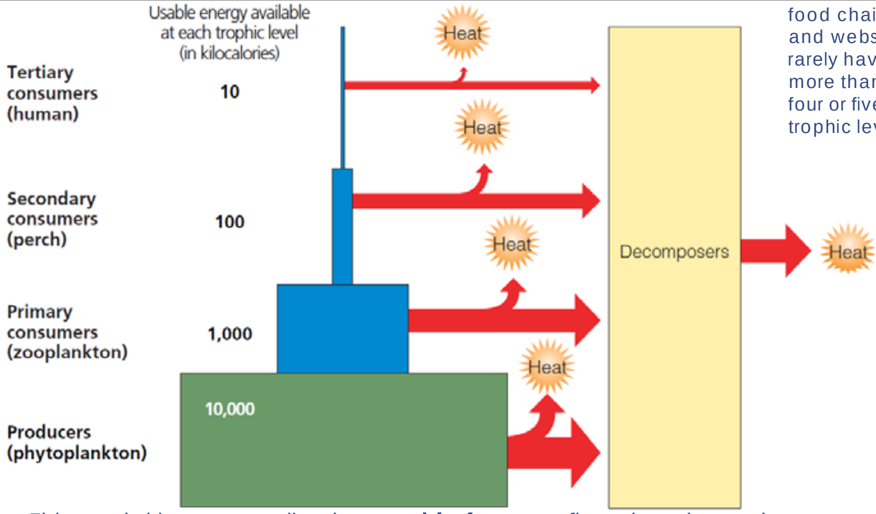
freshwater phytoplankton

27

Usable Energy Decreases with Each Link in a Food Chain or Web

- Each trophic level in a food chain or web contains a certain amount of **biomass** (the dry weight of all organic matter contained in its organisms).
- In a food chain or web, chemical energy stored in biomass is transferred from one trophic level to another.
- As energy flows through ecosystems in food chains and webs, there is a decrease in the amount of high-quality chemical energy available to organisms at each succeeding feeding level
- With each transfer, some usable chemical energy is degraded and lost to the environment as low-quality heat.

28



food chains and webs rarely have more than four or five trophic levels

This model is a generalized **pyramid of energy** flow that shows the decrease in usable chemical energy available at each succeeding trophic level in a food chain or web.

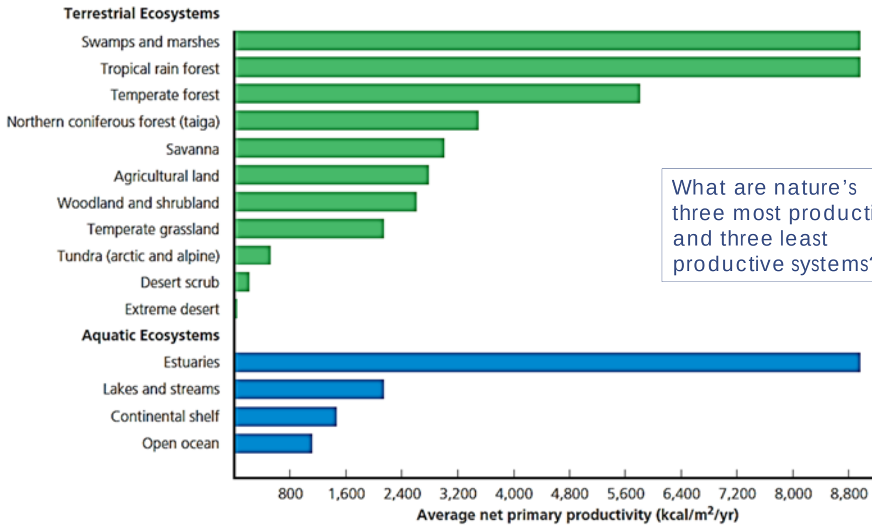
Why there are fewer tigers in tropical rain forests than there are insects?

29

Some Ecosystems Produce Plant Matter Faster Than Others Do

- The amount of living organic material (biomass) that a particular ecosystem can support is determined by
  - how much solar energy its producers can capture and store as chemical energy.
  - how rapidly they can do so.
- **Primary productivity** is the rate at which an ecosystem's producers convert solar energy into chemical energy in the form of biomass found in their tissues.
- It is usually measured in (kcal/m^2/yr)
- To stay alive, grow, and reproduce; producers must use some of the chemical energy stored in the biomass they make for their <u>own respiration</u>.
- **Net primary productivity (NPP)** is the *rate* at which producers use photosynthesis to produce and store chemical energy minus the rate at which they use some of this stored chemical energy through aerobic respiration.

30



What are nature's three most productive and three least productive systems?

- Only the biomass represented by NPP is available as nutrients for consumers, and they use only a portion of this amount.
- Thus, the planet's NPP ultimately limits the number of consumers (including humans) that can survive on the earth. This is an important lesson from nature.

31

Glossary

Environment All external conditions, factors, matter, and energy, living and nonliving, that affect any living organism or other specified system.

Ecology Biological science that studies the relationships between living organisms and their environment; study of the structure and functions of nature.

Ecosystem One or more communities of different species interacting with one another and with the chemical and physical factors making up their nonliving environment.

32

Department of Civil Engineering
College of Engineering
King Saud University

GE 302 – Industry and the Environment
Topic 2

Hydrologic & Nutrients Cycle

What Happens to Matter in an Ecosystem?

Matter, in the form of **nutrients and water**, **cycles** within and **among ecosystems** and the **biosphere**, and human activities are altering these cycles.

Nutrients Cycle within and among Ecosystems

- The elements and compounds that make up nutrients **move continually through air, water, soil, and living organisms** within ecosystems, as well as in the biosphere in cycles called **nutrient cycles,** or biogeochemical cycles.
- These cycles include the hydrologic (water), carbon, nitrogen, and phosphorus cycle.
- These cycles driven directly or indirectly by incoming **solar energy** and the **earth's gravity**

The hydrologic cycle

- The **hydrologic cycle**, or **water cycle**, collects, purifies, and distributes the earth's fixed supply of water.
- The water cycle is powered by energy from the sun and involves three major processes: **evaporation**, **precipitation**, and **transpiration**.
- When precipitation fall on terrestrial ecosystems it:
  - can become **surface runoff** that flows into streams.
  - seeps into the upper layers of soils where it is **used by plants**.
  - some **evaporate** from top soil to atmosphere.
  - sinks through soil to underground layers of rock, sand, and gravel called aquifers, where it is stored as **groundwater**.

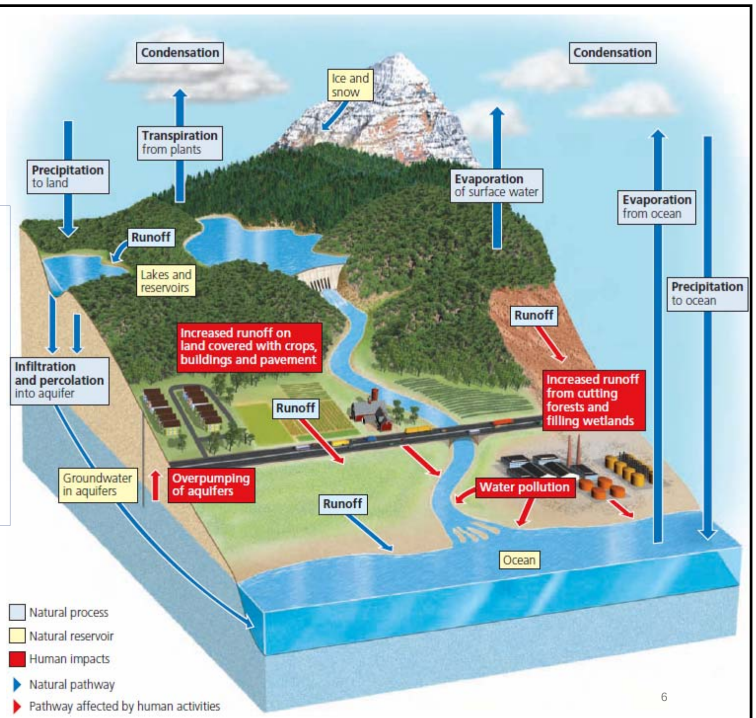
- A small amount of the earth’s water ends up in the living components of ecosystems. As producers, plants absorb some of this water through their roots, most of which evaporates from plant leaves back into the atmosphere during **transpiration.**

- Because water **dissolves many nutrient compounds**, it is a major medium for **transporting nutrients** within and between ecosystems.

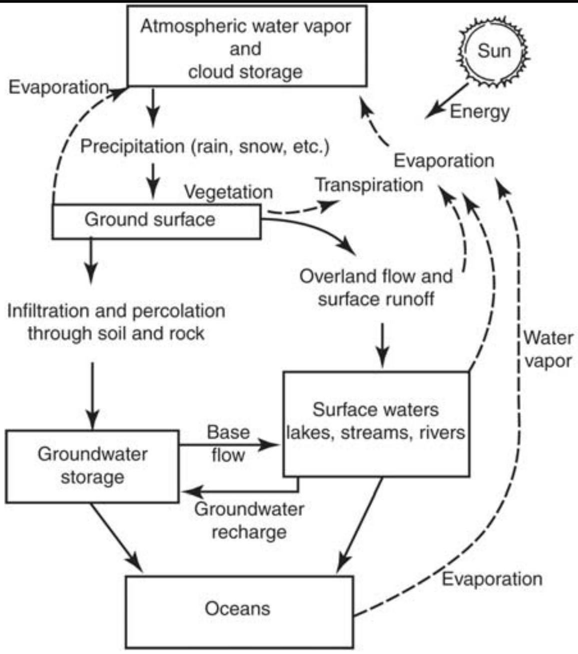
- Only about 0.024% of the earth’s vast water supply is available to humans and other species as **liquid freshwater**

5

Simplified model of the hydrologic cycle, in which water circulates in various physical forms within the biosphere. Major harmful impacts of human activities are shown by the red arrows and boxes



6



Schematic diagram of the natural hydrologic cycle. The constant circulation of water is powered by energy from the sun and by gravity.

Human Activity Alter Water Cycle

- We alter the water cycle in three major ways (see the red arrows and boxes in Figure):
  - First, we **withdraw large quantities of freshwater** from streams, lakes, and aquifers sometimes at rates faster than nature can replace it.
  - Second, we **clear vegetation from land** for agriculture, mining, road building, and other activities, and cover much of the land with buildings, concrete, and asphalt.

    This increases runoff, reduces infiltration that would normally recharge groundwater supplies, accelerates topsoil erosion, and increases the risk of flooding.
  - Third, we also increase flooding when we **drain and fill wetlands** for farming and urban development.

    wetlands provide the natural service of flood control, acting like sponges to absorb and hold overflows of water from drenching rains or rapidly melting snow.

Jeddah floods, 2009

Natural Water Purification Processes

- Throughout the hydrologic cycle, many natural processes purify water.
  - **Evaporation and subsequent precipitation** act as a natural distillation process that removes impurities dissolved in water.
  - **Water flowing above ground** through streams and lakes is partially purified by chemical and biological processes (due to natural aeration and decomposer bacteria).
  - Water flowing below ground in aquifers is **naturally filtered by soil**.
- The hydrologic cycle can be viewed as a cycle of **natural renewal of water quality**.

The Carbon Cycle

- Carbon is the basic building block organic compounds necessary for life.
- Various compounds of carbon circulate through the biosphere, the atmosphere, and parts of the hydrosphere, in the **carbon cycle.**
- The carbon cycle is **based on carbon dioxide** (CO_2) gas, which makes up 0.039% of the volume of the earth's atmosphere and is also dissolved in water.
- Carbon dioxide (along with water vapor in the water cycle) is a key component of the **atmosphere's thermostat.**
  - If the carbon cycle removes too much CO_2 from the atmosphere (*Cooler*)
  - if the carbon cycle generates too much CO_2 to the atmosphere (*Warmer*)

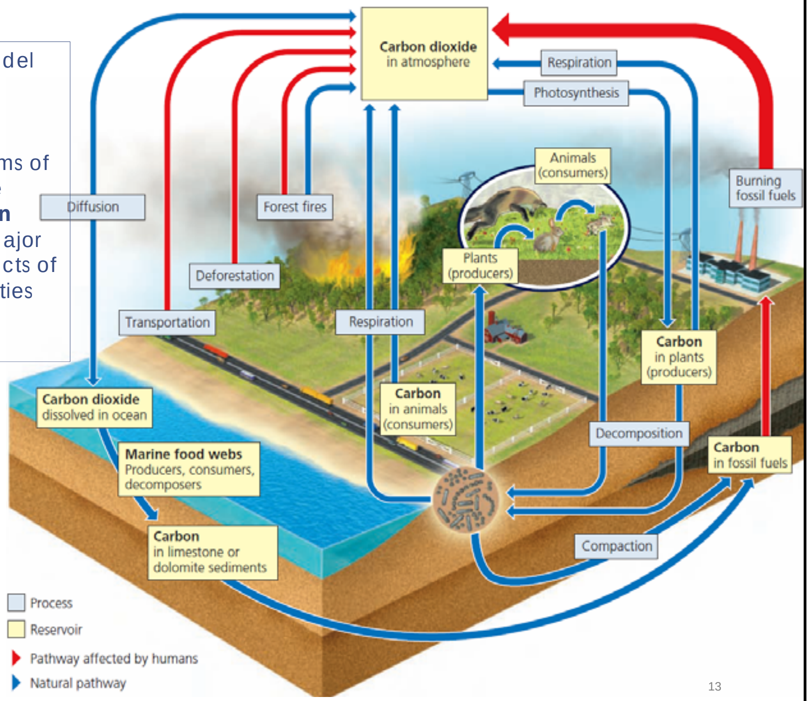
11

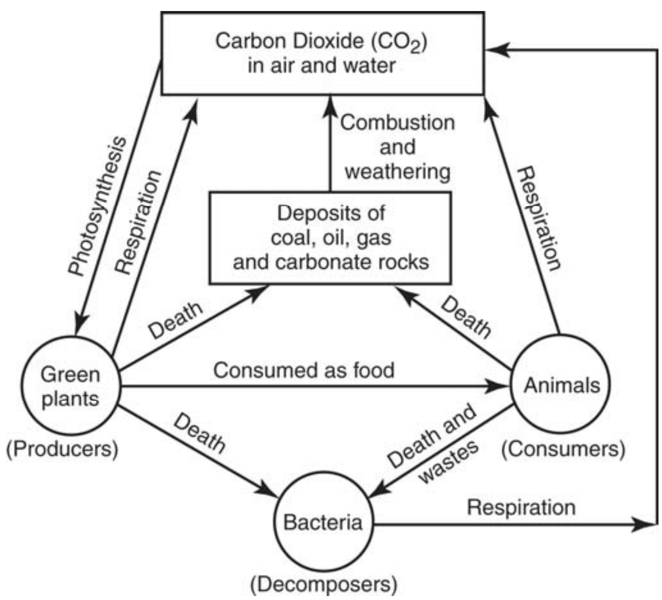
The Carbon Cycle

- **Decomposers release** the carbon stored in the bodies of dead organisms on land back into the air as CO_2.
- In water, decomposers release carbon that can be stored as insoluble carbonates in bottom sediment.
- **Marine sediments** are the earth's largest store of carbon.
- Over millions of years, **buried deposits of dead plant** matter and bacteria are compressed between a layers of sediment, where high pressure and heat convert them to **carbon-containing fossil fuels** such as coal, oil, and natural gas.
- We have extracted and burned huge quantities of fossil fuels that took millions of years to form. This is why, **on a human time scale**, **fossil fuels are nonrenewable resources**.

12

Simplified model illustrates the circulation of various chemical forms of carbon in the global **carbon cycle**, with major harmful impacts of human activities shown by the red arrows.



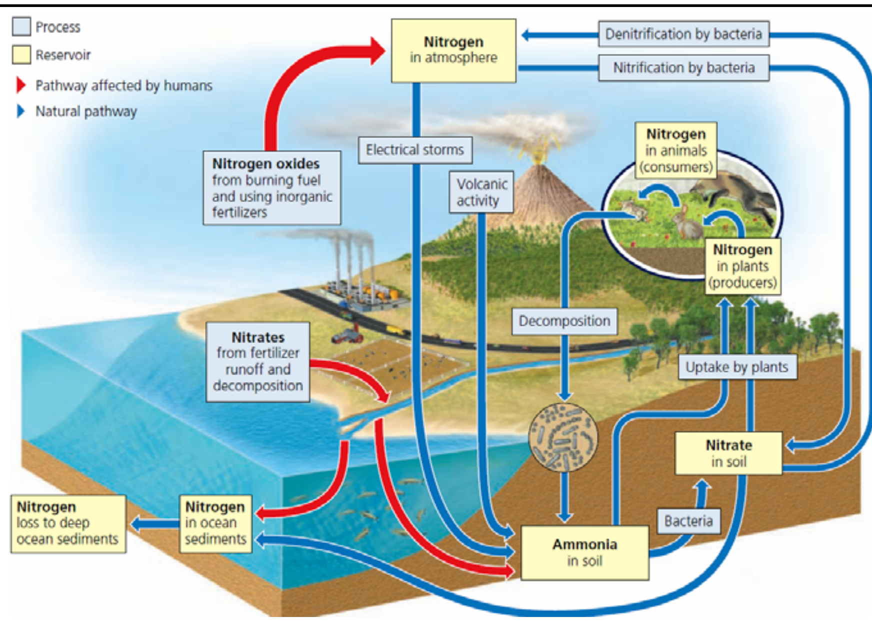


Simplified diagram of the carbon cycle. The arrows show the various directions of carbon transfer through the biosphere.

The Nitrogen Cycle

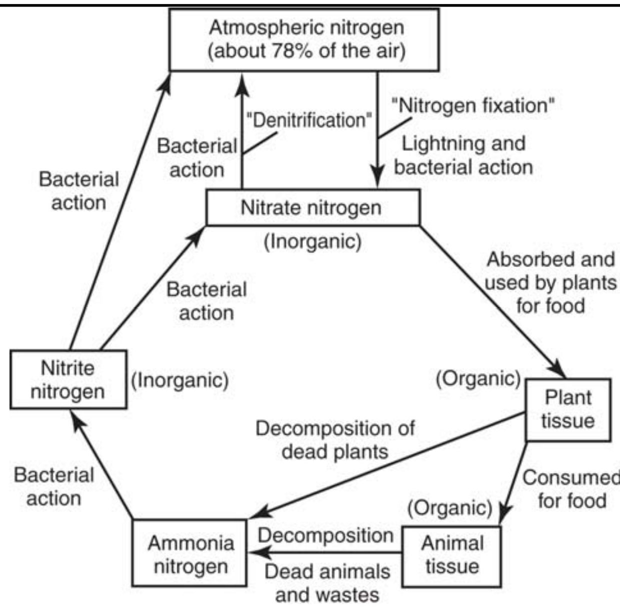
- The major reservoir for nitrogen is the atmosphere. Chemically unreactive **nitrogen gas (N_2)** makes up 78% of the volume of the atmosphere.
- Nitrogen is a crucial component of proteins, many vitamins, and nucleic acids such as DNA.
- N_2 **cannot be** absorbed and **used directly** as a nutrient by plants or animals.
- Two natural processes convert, or fix, N_2 into compounds that plants and animals can use as nutrients.
  1. **Electrical discharges**, or lightning, taking place in the atmosphere. (Nitrogen, N_2 → Ammonia, NH_3)
  2. **Nitrogen fixation** takes place in aquatic systems, in soil, and in the roots of some plants, where specialized bacteria, called **nitrogen-fixing bacteria**, complete this conversion. (Nitrogen, N_2 → Nitrate, NO_3^- → Ammonia, NH_3)

15



A simplified model of the circulation of various chemical forms of nitrogen in the **nitrogen cycle** in a terrestrial ecosystem, with major harmful human impacts shown by the red arrows.

16

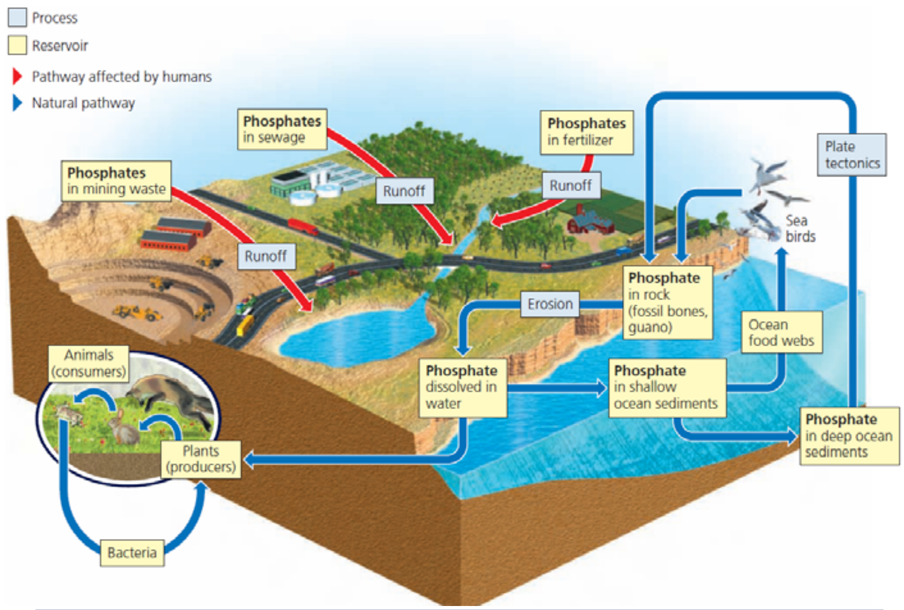


Simplified diagram of the nitrogen cycle. Molecular nitrogen must first be fixed (combined with oxygen) into the form of nitrate nitrogen before it can be used by plants as a nutrient.

The Phosphorus Cycle

- Compounds of phosphorous (P) circulate through water, the earth's crust, and living organisms in the **phosphorus cycle**. The phosphorus cycle does not include the atmosphere.
- **phosphate ions** (PO_4^{3-}) serve as an important nutrient.
- The major reservoir for phosphorous is phosphate salts containing phosphate ions in terrestrial **rock formations** and **ocean bottom sediments**.
- The phosphorus cycle is slow compared to the water, carbon, and nitrogen cycles.
- For both producers and consumers, phosphates are a component of biologically important molecules such as **nucleic acids**.
- Because most soils contain little phosphate, the lack of it often **limits plant growth** on land unless phosphorus is applied to the soil as a fertilizer.

18



a simplified model of the circulation of various chemical forms of phosphorus (mostly phosphates) in the **phosphorus cycle**, with major harmful human impacts shown by the red arrows.

19

Eutrophication

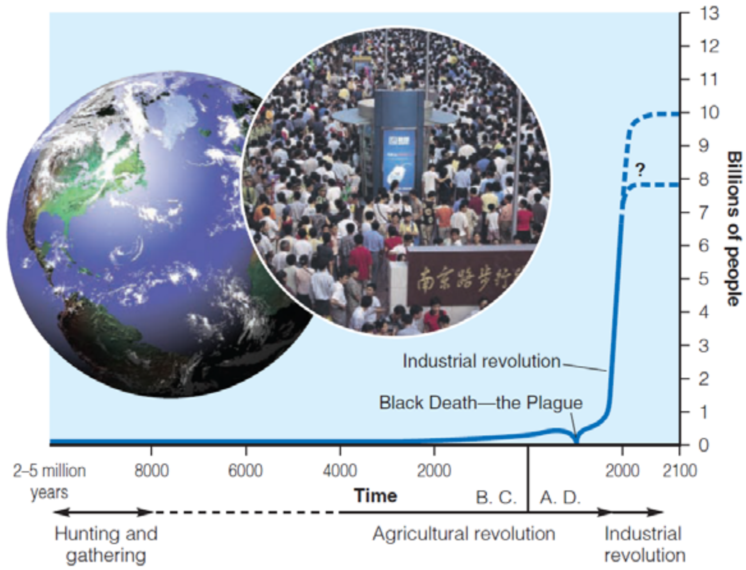
- **Eutrophication** is a process whereby water bodies, such as lakes, estuaries, or slow-moving streams receive excess nutrients (nitrogen and phosphorus) that stimulate excessive growth of algae or phytoplankton (**algae blooms**).
- This algae bloom reduces dissolved oxygen in the water and after dying its decomposition consume more oxygen and makes water **hypoxic** (water with low concentration of dissolved oxygen).
- Hyperoxic water is the water with high concentration of oxygen.

20

Department of Civil Engineering
College of Engineering
King Saud University

GE 302 – Industry and the Environment
Topic 3

The human population and its impact

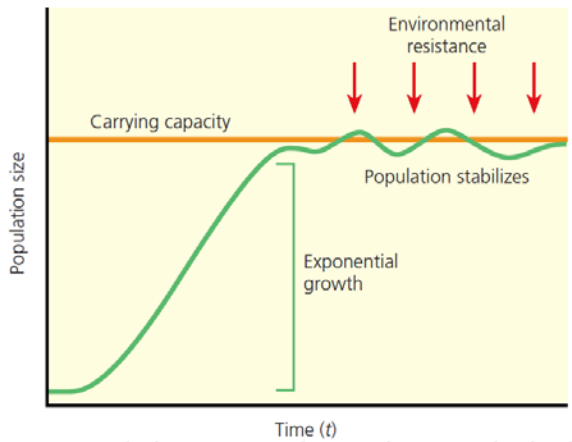


For most of history, the human population grew slowly. But for the past 200 years, the human population has grown rapidly, resulting in the characteristic J-curve of exponential growth

Three major factors account for population increase in the past 200 years:

1. **Modern agriculture technique** allow to grow more food.
2. **Death rates drop** because of improved sanitation and health care and development of antibiotics and vaccines to help control infectious diseases.
3. **Humans adaptability** to live in any climate zones and habitats.

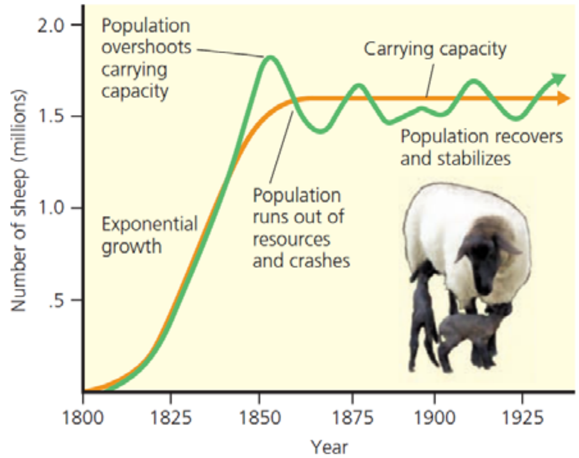
- Most of the increase in the world's population during the last 100 years took place because of **a sharp drop in death rates** – not a sharp rise in birth rates.



Carring capacity
Maximum population of a particular species that a given habitat can support over a given period

Environmental resistance that case the caring capacity is: **shrinkage in resources such as food, water, and space**

- **No population can continue to increase in size indefinitely**. Exponential growth occurs when a population has essentially unlimited resources to support its growth.
- Such exponential growth is eventually converted to logistic growth, in which **the growth rate decreases as the population becomes larger and faces environmental resistance** (right half of the curve).
- Over time, the population **size stabilizes at or near the carrying capacity** of **its environment**, which results in a sigmoid (S-shaped) population growth curve.



- This graph tracks the logistic growth of a sheep population on the island of Tasmania between 1800 and 1925.
- After sheep were introduced in 1800, their population grew exponentially. By 1855, they had overshot the land's carrying capacity. Their numbers then stabilized and fluctuated around a carrying capacity of about 1.6 million sheep.

5

The eight major ways in which we humans have altered natural systems to meet our growing population's resource needs (**causes of natural capital degradation**):

1. Reducing biodiversity.
2. Increasing use of net primary productivity.
3. Increasing genetic resistance in pest species and disease-causing bacteria.
4. Eliminating many natural predators.
5. Introducing harmful species into natural communities.
6. Using some renewable resources faster than they can be replenished.
7. Disrupting natural chemical cycling and energy flow.
8. Relying mostly on polluting and climate-changing fossil fuels.

6

What Factors Influence the Size of the Human Population?

- The average number of children born to women in a population (total fertility rate) is **the key factor that determines population size**.
- Population size increases through births (**fertility**) and immigration, and decreases through deaths (**mortality**) and emigration.
- **Population change** =

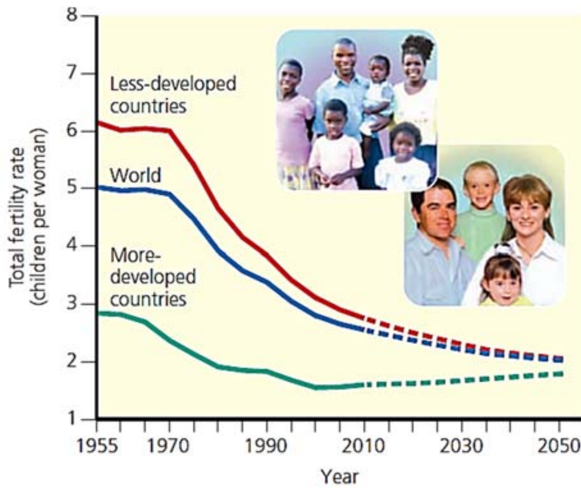
(Births + Immigration) – (Deaths + Emigration)

7

- **Fertility rate**: the number of children born to a woman during her lifetime.
- Two types of fertility rates affect a country's population size and growth rate:

1. **Replacement-level fertility rate**
   - is the average number of children that couples in a population must bear to replace themselves.
   - It is slightly higher than two children per couple: 2.1 in more-developed countries and as high as 2.5 in some less-developed countries.
2. **Total fertility rate** (**TFR**)
   - is the **average number** of children born to women **in a population** during their reproductive years.
   - This factor plays a key role in determining population size

8



This graph tracks the total fertility rate for both the more-developed and less-developed regions of the world, 1955 – 2010, with projections to 2050

Between 1955 and 2010, the average TFR dropped from 2.8 to 1.7 children per woman in more-developed countries and from 6.2 to 2.7 in less-developed countries.

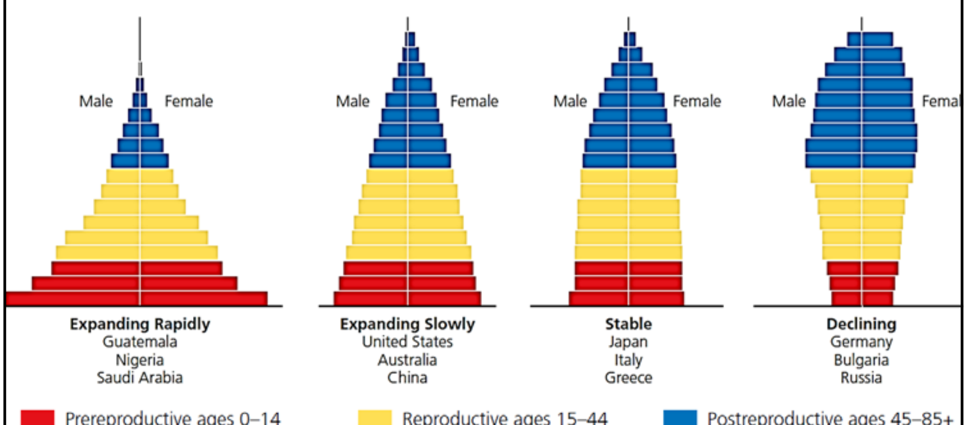
- Two useful indicators of the overall **health of people in a country** or region are:
  - **Life expectancy** (the average number of years an individual can be expected to live)
    - o In 2010, Japan had the world's longest life expectancy of 83 years.
    - o In the world's poorest countries, life expectancy is 57 years or less.
  - **Infant mortality rate** (the number of babies out of every 1,000 born who die before their first birthday).
    - o Infant mortality is viewed as one of the best measures of a society's quality of life because it reflects a country's general **level of nutrition and health care**.

Several Factors Affect Death Rates:

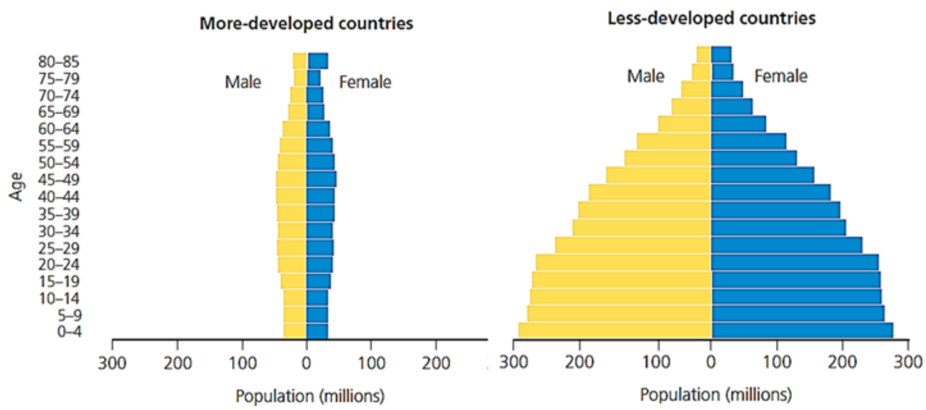
- Increased food supplies and distribution, better nutrition.
- Medical advances such as immunizations and antibiotics.
- improved sanitation, and safer water supplies.

How Does a Population's Age Structure Affect Its Growth or Decline?

- **Age structure** is the numbers or percentages of males and females in young, middle, and older age groups in that population.
- Population experts construct a population **age structure diagram** by plotting a given population's percentages of males and females in each of three age categories:
  - **Pre-reproductive** (ages 0–14), consisting of individuals normally too young to have children
  - **Reproductive** (ages 15–44), consisting of those normally able to have children
  - **Post-reproductive** (ages 45 and older), with individuals normally too old to have children.



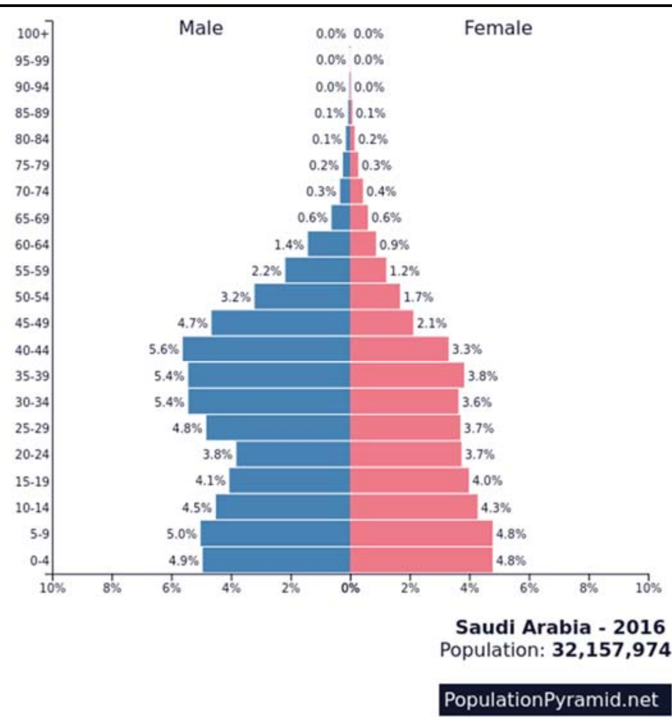
This chart represents the generalized population age-structure diagrams for countries with rapid (3 – 1.5%), slow (1.4 – 0.3%), zero (0.2 – 0%), and negative (declining) population growth rates.



Global outlook: These charts illustrate population structure by age and sex in less-developed countries and more-developed countries for 2010

Even if the global replacement level fertility rate of 2.1 children per woman were magically achieved tomorrow, the world's population would keep growing for at least another 50 years. This continued growth results from a population's age structure.

Population Pyramid of Saudi Arabia



How Can We Slow Human Population Growth?

We can slow human population growth by:

1. Reducing poverty, through economic development and education.
2. Empowering Women, by elevating the status of women.
3. Promote Family Planning

Three big ideas learned from this topic:

- The human population is increasing rapidly and may soon bump up against **environmental limits**.
- Even if population growth were not a serious problem, the increasing use of resources per person is expanding the overall human ecological footprint and **putting a strain on the earth's resources**.
- We can slow human population growth by reducing poverty through economic development, elevating the status of women, and encouraging family planning.

Department of Civil Engineering
College of Engineering
King Saud University

GE 302 – Industry and the Environment
Topic 4

Water Pollution

part-1

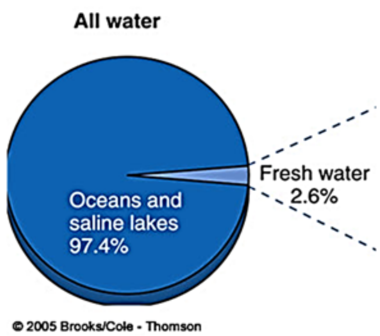
- Introduction
- Parameter of Water Quality

Facts about water

- Water is an integral part of life on this planet.
- It is an odorless, tasteless, substance that covers more than three-fourths of the Earth's surface.
- **Most of the water** on Earth, 97.4% to be exact, **is salt** water found in the oceans.
- Water has such a strong tendency to dissolve other substances (universal solvent).
- We cannot drink salt water or use it for crops because of the salt content.
- We can remove salt from ocean water, but the process is very expensive

2

Global Distribution of Earth's Water



- Water surfaces constitute 70% of the earth's surface.
- Seas and oceans (saltwater) forms approximately 97.4% of the earth's water; i.e. only 2.6% is fresh water.
- Only small fraction (0.014%) in rivers, lakes and springs is readily available for human use

Three Forms of Water

- **Solids**: When water becomes very cold and freezes it will change from a liquid to a solid. It has a definite form and shape.
- **Liquids**: When water takes the shape of its container it is in a liquid form.
- **Gases**: When water is seen in a vapor form and has no definite size or shape it is in a gas form.

Water Resources

- Surface Water (rivers, lakes, springs)
- Groundwater (difficult to obtain)
- Ocean & Seawater (not economic to Desalinize)
- Reclaimed water (Treated Wastewater)

Percent of World's Total Freshwater in Different Locations The total amount of freshwater on Earth is approximately 3.5×10^7 km^3

Location	Percent of World's Freshwater
Glaciers and permanent snow cover	68.7
Groundwater	30.1
Lakes	0.26
Soil moisture	0.05
Atmosphere	0.04
Marshes and swamps	0.03
Biological water	0.003
Rivers	0.006

SOURCE: Data from UNESCO-WWAP, 2003.

Source of Water & issues Associated with the Source

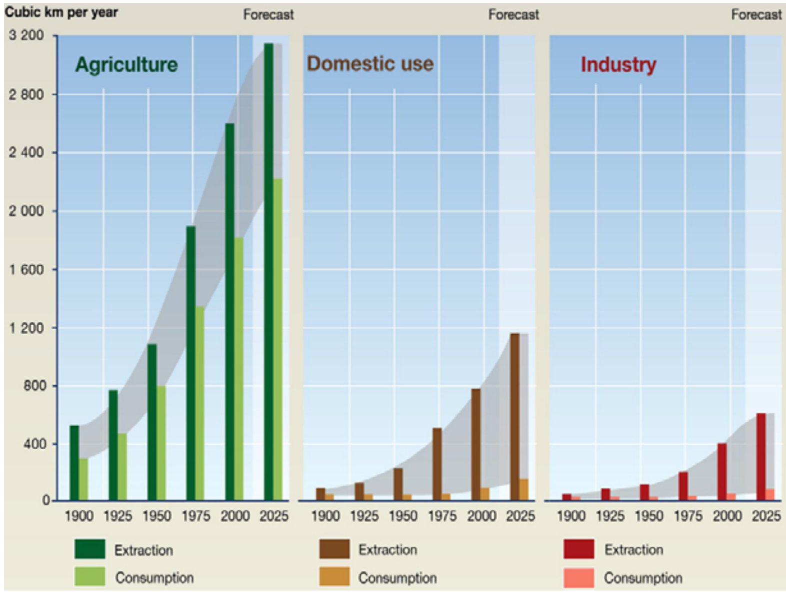
Source of Water	Issues
Surface water	High flows, easy to contaminate, relatively high suspended solids (total suspended solids, TSS), turbidity, and pathogens. In some parts of the world, rivers and streams dry up during the dry season.
Groundwater	Lower flows but natural filtering capacity that removes suspended solids (TSS), turbidity, and pathogens. May be high in dissolved solids (total dissolved solids, TDS), including Fe, Mn, Ca, and Mg (hardness). Difficult to clean up after contaminated. Renewal times can be very long.

Source of Water & issues Associated with the Source

Source of Water	Issues
Seawater	Energy-intensive to desalinate, so costly compared with other sources, and disposal of resulting brine must be considered. Desalination can occur by distillation, reverse osmosis, electrodialysis, and ion exchange. Of these, multistage distillation and reverse osmosis are the two technologies most commonly used (they account for approximately 87 percent of worldwide desalination capacity). There are more reverse osmosis plants in the world; however, they are typically smaller in capacity than distillation plants.

Source of Water & issues Associated with the Source

Source of Water	Issues
Reclaimed and reused	Technically feasible. Currently used for irrigating agricultural crops, residential and commercial landscaping, groundwater recharge, and potable water through direct and indirect use. Includes decentralized use of gray water (wastewater produced from baths and showers, clothes and dishwashers, lavatory sinks, and drinking-water fountains). When used. for irrigation, nutrients present in reclaimed water can reduce fertilizer usage.



Trends in global water use by sector

The Grey band represents the difference between the amount of water extracted and that actually consumed.

9

Water Quantity Estimation

The quantity of water required for municipal uses for which the water supply scheme has to be designed requires following data:

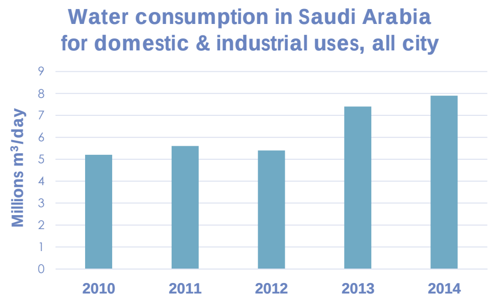
1. Water consumption rate (liters per day per capita) (LPCD)
2. Population to be served.

Quantity = Per capita demand (lit/cap/day) x Population (cap)

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)

10



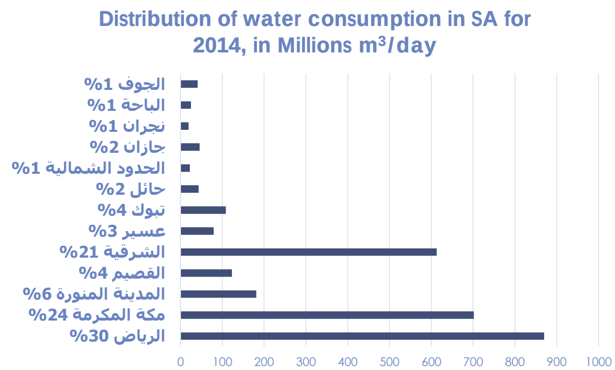
الهيئة العامة للإحصاء
المملكة العربية السعودية

Average water consumption rate in **Saudi Arabia = 275 LPCD**

USA: 575 LPCD

UK: 150 LPCD

Rwanda: 20 LPCD

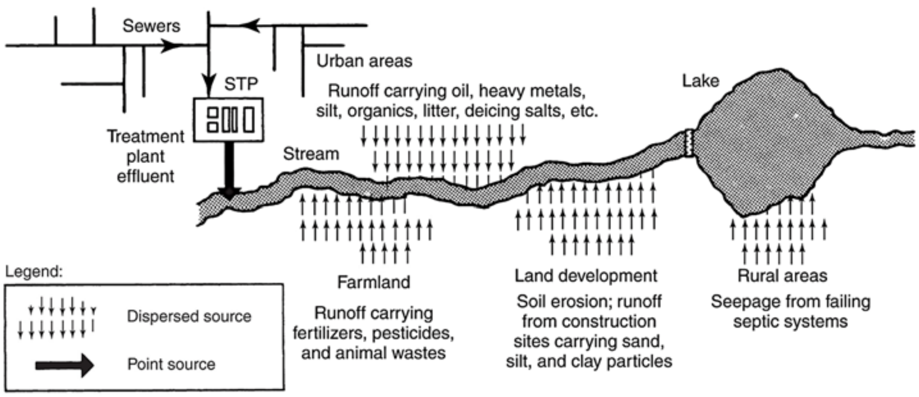


What is water pollution?

- Water pollution is any chemical, biological, or physical change in water characteristics that makes it **unfit for a specific beneficial use**.
- The distinction between polluted and unpolluted water depends on:
  - Type and concentration of impurities.
  - Intended use of water
- Water pollution occurs when pollutants are discharged directly or indirectly into water bodies without adequate treatment to remove harmful compounds.
- Water pollution affects plants and organisms living in these bodies of water, which can result in damaging natural biological system.

Two Types of Pollution Sources

A pollutant can be classified according to the nature of its origin either a **point source** or a **dispersed source** pollutant.



Dispersed source pollutants are more difficult to control than are point source pollutants, which can be collected and removed from the water.

- Dispersed sources cause a significant fraction of the water pollution that may exceed sewage pollution, especially from stormwater runoff in urban as well as rural areas.
- Water pollutants can be classified into groups of substances based primarily on their **environmental impacts**, or **effects on human health.**
- **Generic types of water pollutants:**
  1. Pathogenic organisms
  2. Oxygen-demanding substances
  3. Plant nutrients
  4. Toxic organics
  5. Inorganic chemicals
  6. Sediment
  7. Radioactive substances
  8. Heat
  9. Oil

Sources of Water Pollution due to Human Activities

1. Domestic Sewage (Wastewater):

- the primary sources of the first three types of pollutants.
- Pathogens, or **disease-causing microorganisms**, are excreted in the feces of infected persons and may be carried into waters receiving sewage discharges.
- Oxygen-demanding substances: the organic wastes that exert a biochemical oxygen demand (BOD) as they are decomposed by microbes.

2. Agricultural activities:

- The major source of water pollution is agriculture according to the US Environmental Protection Agency (EPA).

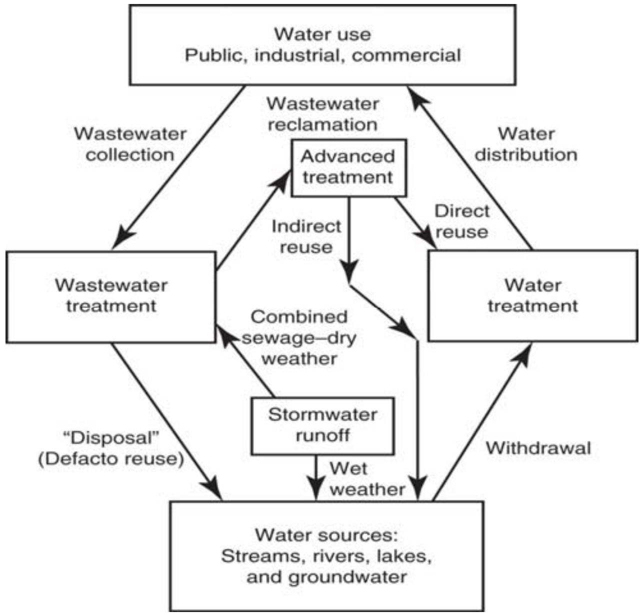
- Farming is a source of silt, as well as nutrients, pesticides, and organic material.

3. Industrial activities:

- Industry is a huge source of water pollution, it produces pollutants that are extremely harmful to people and the environment.
- This wastewater may contain toxic chemicals, acids, alkalis, salts, poisons, oils and in some cases harmful bacteria.

4. Oil spill in oceans:

- Oceans are polluted by oil on a daily basis from oil spills, routine shipping, run-offs and dumping.



Urban Water Cycle (Induced by human)

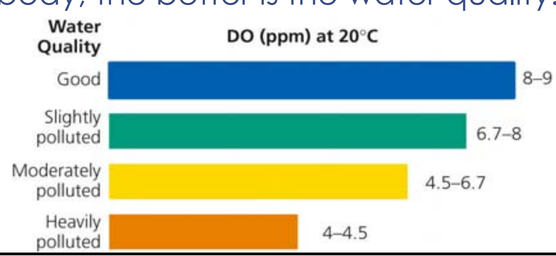
Parameters of Water Quality

1. **Physical Water Quality**
   – Turbidity, Color, Taste & Odor, Total Solids, Suspended Solids, Total Dissolved Solids, Temperature, etc.
2. **Chemical Water Quality**
   – pH, Alkalinity, Hardness, Chlorides, Fe and Manganese, Sulfates, Nitrogen compounds, Dissolved oxygen, Biological oxygen demand, Chemical oxygen demand, etc.
3. **Microbiological Water Quality**
   – Microorganism: Bacteria, Algae, Protozoa, Viruses
   – Indicator organism: Coliforms

- **Total Suspended Solids (TSS)**
  - include colloids, supra-colloids, and settleable solids.
- **Total Dissolved Solids (TDS)**
  - Dissolved Solids are the solids that can be recovered from water by evaporating the water after filtering the suspended solids
- **Total Solids (TS)**
  - Total solids in water and wastewater include suspended solids and dissolved solids (TS= TSS + TDS).
- **Color**
  - Types: **True color** caused by dissolved solids; **Apparent color** caused by suspended solids and includes true color.
  - Measured by Colorimeter or Spectrophotometer (Units: True Color Unit)

19

- **Turbidity**
  - Turbidity measures the clarity of water containing colloidal material (cloudy water).
  - Measured by Turbidimeter (Units: Nephlometric Turbidity Unit, **NTU**)
- **Dissolved Oxygen (DO)**
  - Dissolved Oxygen (DO) is generally considered to be one of the most important parameters of water quality in streams, rivers, and lakes.
  - The higher the concentration of dissolved oxygen in water body, the better is the water quality.



20

- **pH (hydrogen ion concentration)**
  - o Water (H_2O) dissociate slightly to H^+ and OH^-:

$$H_2O \leftrightarrow H^+ + OH^-$$

  - o pH is an intensity factor.
    - pH = 7: Neutral
    - pH < 7: Acidic
    - pH> 7: Alkaline
  - o pH of most raw water sources: 6.5 - 8.5
  - o Significance:
    - Influences the chemical and biological reactions in water and wastewater treatment plant respectively.
    - Corrosion problems (low pH)
    - Many industrial waters require rigid pH control
    - Optimum pH required for fish and other aquatic life

21

- **Alkalinity**
  - Ability of water to neutralize acids (buffering capacity of water).
  - Alkalinity is mostly due to bicarbonates (**HCO_3^-**), of Ca, Mg, and Na.
  - Highly alkaline water often has a high pH and generally contains high levels of dissolved solids (harmful for water to be used in boilers and food processing).
  - Significance:
    - Prevent sudden change of pH in aquatic system
    - Influences the chemical and biological reactions in water and wastewater treatment plant respectively.

22

- **Hardness**
  - Hardness is a characteristics of water that **prevents lathering of soap** and **produces scale in hot water pipes and heaters**
  - Hardness is due to the presence of calcium (Ca) and magnesium (Mg) which is common in groundwater
  - Significance:
    - Scale build-up in boilers and hot water pipe
    - Excessive soap usage
    - Spotted dishes, glasses and silverware



- **Iron (Fe) and Manganese (Mn)**
  - Ground waters that are devoid of dissolved oxygen can contain appreciable amounts of (Fe^{2+}) & (Mn^{2+}).
  - Iron in concentrations greater than 0.3 mg/L and manganese in concentrations greater than 0.05 mg/L is considered significance.
  - Significance:
    - Brown and black stains on laundry and plumbing fixtures
    - A metallic taste of water may be present.
- **Trace Metals**
  - Trace metals include those metals that are harmful and toxic in relatively small amounts.
  - The main source of these metals is the discharges of industrial wastewater.
  - Examples of trace metals: arsenic, cadmium, chromium, mercury, lead, silver and barium.

24

- **Nitrogen compounds**
  - Inorganic: Ammonia NH_3, Nitrite NO_2^-, **Nitrate NO_3^-**
  - Organic: Protein, amino acids
  - Main Sources:
    - Discharge of domestic, agricultural (fertilizers), industrial wastewater.
    - Animal wastes and decomposition of dead plants, animal.
  - Significance:
    - Drinking of water with high nitrate content (NO_3^-) causes Blue-baby disease in infants.
    - Presence of nitrogen compounds along with phosphorus in water bodies cause **eutrophication**

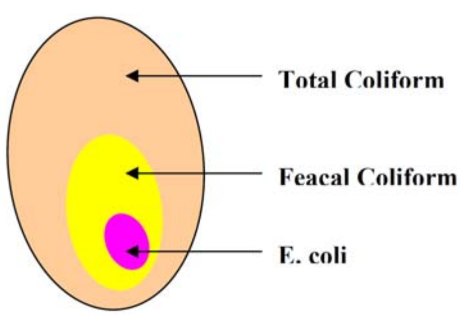
- **Organic Matter**
  - Organic compounds are composed mainly of **carbon and hydrogen** along with other elements such as oxygen, nitrogen, phosphorus, and sulfur.
  - Organics can be classified on the basis of their origin into:
    - Natural organics (e.g. plants and animal tissues, human feces)
    - Synthetic organics (e.g. plastics, rubber)
  - Based on their microbial degradation, organics can be:
    - Biodegradable
    - Non-biodegradable
  - Methods of measurement the organic concentration in water:
    - Biochemical Oxygen Demand, **BOD**
    - Chemical Oxygen Demand, **COD**

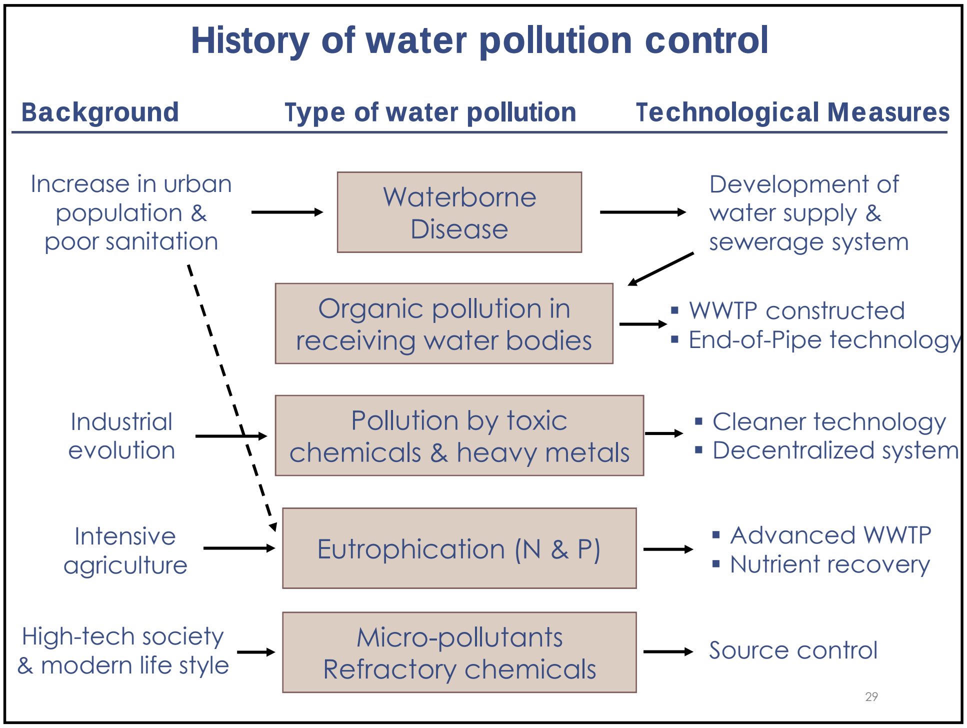
- **Biochemical Oxygen Demand**
  - BOD is the amount of oxygen required (consumed) by microorganisms to biologically degrade organic matter in a water sample.
  - BOD is used to Measure the organic strength of wastewater.

- **Chemical oxygen demand:**
  - COD is the amount of oxygen required to chemically oxidize organics in water.
  - For domestic wastewater, COD > BOD_5 because COD includes both biodegradable and non-biodegradable organics.

Microbiological Water Quality

- Disease causing microorganisms are called **pathogens**
- Indicator organisms for water quality:
  - **Total Coliform** used in laboratory testing referring to all coliform bacteria from faeces, soils or other origin.
  - **Faecal Coliform** refers to coliform bacteria originating from human or animal faeces.




History of water pollution control
Background
Type of water pollution
Technological Measures
Increase in urban population & poor sanitation
Waterborne Disease
Development of water supply & sewerage system
Organic pollution in receiving water bodies
▪ WWTP constructed
▪ End-of-Pipe technology
Industrial evolution
Pollution by toxic chemicals & heavy metals
▪ Cleaner technology
▪ Decentralized system
Intensive agriculture
Eutrophication (N & P)
▪ Advanced WWTP
▪ Nutrient recovery
High-tech society & modern life style
Micro-pollutants Refractory chemicals
Source control
29

Department of Civil Engineering
College of Engineering
King Saud University

GE 302 – Industry and the Environment
Topic 4

Water Pollution
part-2
- Type of Water Pollution
- e.g. of Water Pollution Control

Type of Water Pollution:

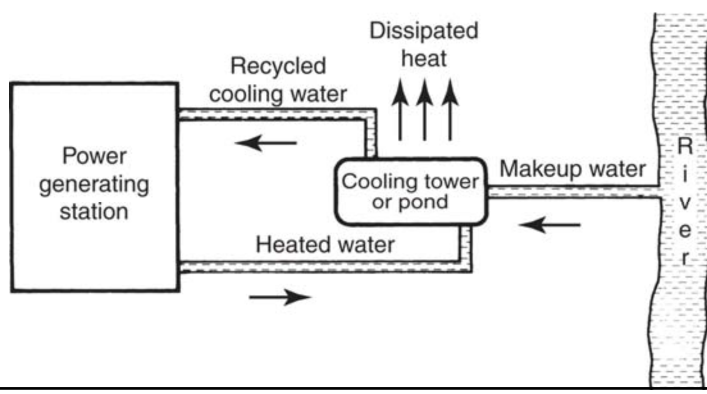
1. Thermal Pollution
2. Soil Erosion and sediment Control
3. Stream Pollution
4. Lake Pollution
5. Groundwater Pollution
6. Ocean Pollution

2

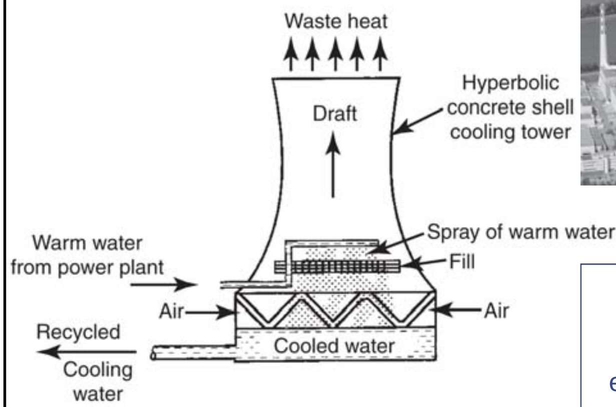
1. Thermal Pollution

- Heat is considered to be a water pollutant because of the adverse effect it can have on the **oxygen levels** and the **aquatic life** in a river or lake.
- The discharge of warm water into a river is usually called thermal pollution.
- Discharge of warm water is caused mainly for cooling purposes for power plants.
- The warmer temperature **decrease the solubility of oxygen** and increases the rate of metabolism of fish.
- Some species of fish actually prefer warmer waters.

- Thermal pollution may by controlled by **passing the heated water through a cooling pond or a cooling tower** after it leaves the condenser.
- The **heat is dissipated into the air**, and the water can then be either discharged to the river or pumped back to the plant for reuse as cooling water



- In locations where there is not enough room for a cooling pond, one or more cooling towers may be built to prevent thermal pollution.



A common type is the **natural draft hyperbolic cooling tower**, in which evaporation accounts for most of the heat transfer

5

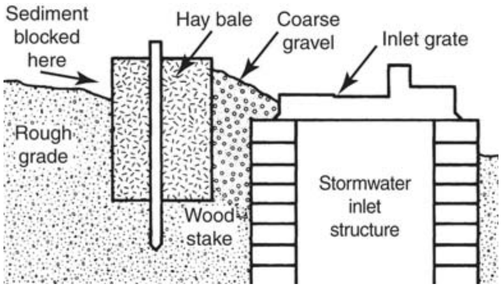
2. Soil Erosion and sediment Control

- The natural movement of soil particles by wind or water from one location to another is called **soil erosion**.
- Soil erosion has been identified as one of the sources of water pollutants.
- Soil particles suspended in water interfere with the penetration of sunlight.
- This in tum reduces photosynthetic activity of aquatic plants and algae, disrupting the ecological balance of the stream.
- There are two types of water-caused soil erosion:
  - **sheet erosion** from land areas by raindrop impact and overland flow of storm runoff.
  - **stream erosion** or the removal of soils from streambeds and stream banks by the swiftly moving channelized water.

6

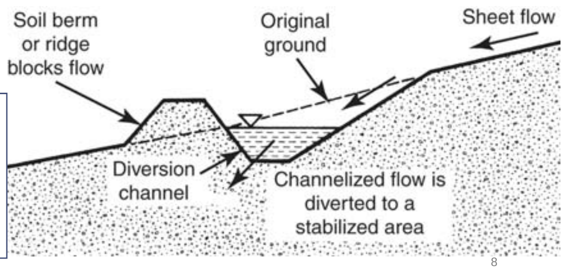
- When the water velocity decreases, the suspended particles settle out and are deposited as **sediment** at the bottom of the stream or lake.
- Sediment smothers **benthic**, or bottom-dwelling, organisms and disrupts the reproductive cycles of fish and other life forms.
- Some of the more common best management practices (**BMPs**) include the following:
  - Temporary grass cover on exposed soils to reduce wind and water erosion.
  - Hay bales can be placed around stormwater inlets to intercept sediment.
  - Diversion channels can be constructed across slopes to reduce open slope length.
  - Channel stabilization for streams and drainage ditches.

7



A typical hay bale and gravel filter, which prevents sediment from entering a drainage system and then local streams, is usually used in the vicinity of active construction sites.

Diversion channels reduce the distance of overland sheet flow, thereby reducing soil erosion and sedimentation of nearby streams and lakes.



8

3. Stream Pollution

- The flowing water carries algae rapidly downstream and tends to discourage the growth of rooted plants on the stream bed.
- **To a limited extent**, streams and rivers have the **ability to assimilate or degrade biodegradable wastes**. Thus, they can recover from the effects of pollution naturally, without significant or permanent environmental damage.
- The capacity for self-purification depends on:
  - the strength and volume of pollutants,
  - the stream discharge or flow rate,
  - the level of turbulence in the water as it may cascade over rocks and boulders in the stream channel
- It used to be said that: **the solution to pollution is dilution**

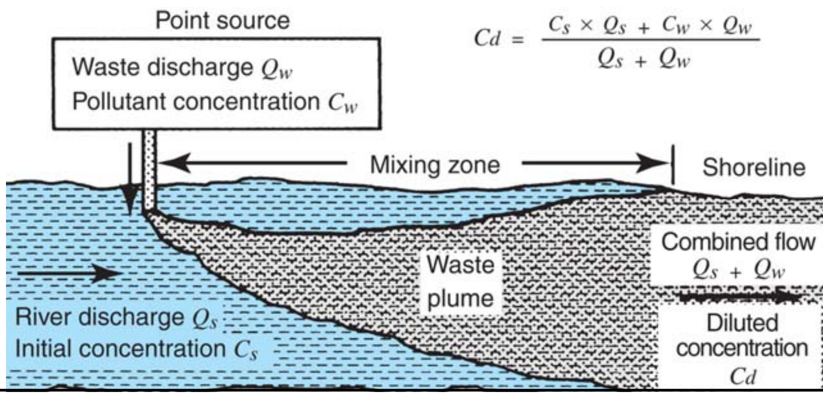
9

- The effect of oxygen transfer between the air and the water (**reaeration**) is important factor for natural purification.
- Fast-flowing, shallow, turbulent streams are reaerated more effectively than slow, deep, twisting streams.
- Modem-day population densities are too high for most streams and rivers to assimilate raw sewage discharges.
- Some degree of treatment is required to remove enough of the BOD from the sewage so that stream can finish the job of the purification.
- A level of treatment called **secondary treatment** is generally sufficient for this purpose; it is the minimum level of treatment required.

10

Dilution

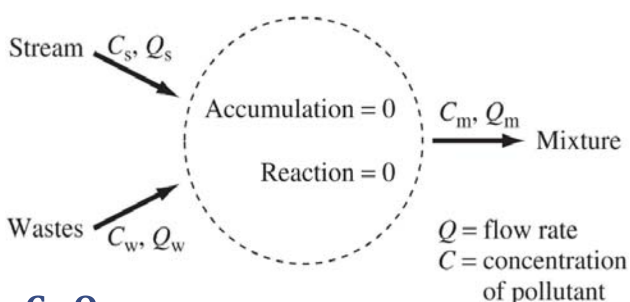
- There are two basic steps involved in the process of waste assimilation in a stream or river:
  1. Physical processes of **dilution** and reaeration occur.
  2. Biological processes occur, in which **microorganisms** in the water use dissolved oxygen to **metabolize organic pollutants** and convert them into harmless substances.



Dilution

- One input to the system is a stream with a flow rate Q_s (volume/time) and pollutant concentration C_s (mass/volume).
- The other input is assumed to be a waste stream with flow rate Q_w and pollutant concentration C_w.
- The output is a mixture with flow rate Q_m and pollutant concentration C_m

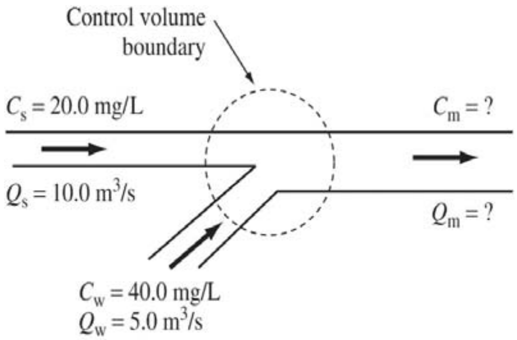
$$Q_s + Q_w = Q_m$$



$$C_sQ_s + C_wQ_w = C_mQ_m$$

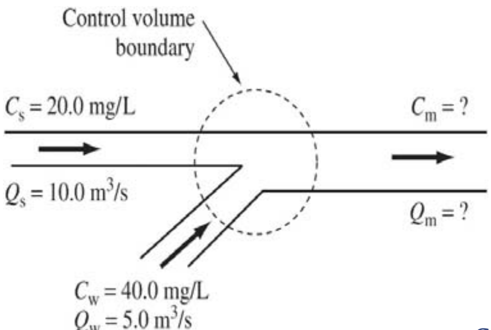
Example_1:

A stream flowing at 10.0 m^3/s has a tributary feeding into it with a flow 5.0 m^3/s. The stream's concentration of chlorides upstream of the junction is 20 mg/L and the tributary chloride concentration is 40 mg/L. Treating chlorides as a conservative substance, and assuming complete mixing of the two streams, find the downstream chloride concentration.



13

Solution



$$C_sQ_s + C_wQ_w = C_mQ_m$$

$$Q_s + Q_w = Q_m$$

$$C_m = \frac{C_sQ_s + C_wQ_w}{Q_m} = \frac{C_sQ_s + C_wQ_w}{Q_s + Q_w}$$

$$C_m = \frac{(20 \times 10 + 40 \times 5)\ \mathrm{mg/L \cdot m^3/s}}{(10 + 5)\ \mathrm{m^3/s}} = 26.7\ \mathrm{mg/L}$$

14

Example_2:

A river has a dry-weather discharge of 100 m^3/s and a temperature of 25°C. Compute the maximum discharge of cooling water at 65°C that can be discharged from a power plant into the stream. Assume the legal limit on temperature increase in the stream is 2°C.

Solution:

The maximum allowable stream temperature is

25+2=27°C

$$C_m = \frac{C_s Q_s + C_w Q_w}{Q_s + Q_w} \longrightarrow 27 = \frac{25 \times 100 + 65 \times Q_w}{100 + Q_w}$$

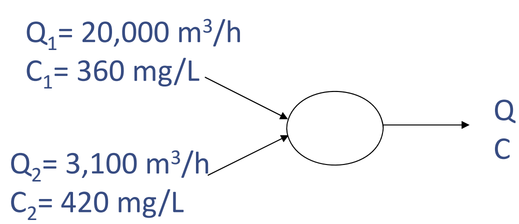
$$2700 + 27\,Q_w = 2500 + 65\,Q_w$$

$$38\,Q_w = 200 \longrightarrow Q_w = 5.3\ m3/s$$

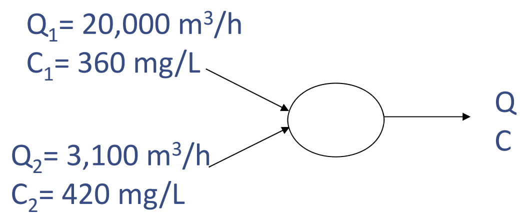
Example_3:

A wastewater treatment plant is discharging to a river. If the water flow rates are given in table, Compute the TDS concentration at the end point, assuming a complete mixing.

	River (before mixing point)	Wastewater Treatment Plant (24 h/day)
Flow rate (m^3/h)	20,000	3,100
TDS (mg/L)	360	420



Solution of example-3:



$Q = Q_1+Q_2 = 20{,}000\ m^3/h + 3{,}100\ m^3/h = 23{,}100\ m^3/h$

$Q_1C_1+Q_2C_2 = 20000 * 360 + 3100 * 420 = 8{,}502{,}000$

$C = [\ Q_1C_1+Q_2C_2\ ] / [\ Q_1+Q_2\ ] = 8{,}502{,}000 / 23{,}100$

$C = 368$ mg/l

- If the wastewater is released during some hours, not continuous flow, **equalization tanks** may be used to reduce the flow rates.

- New flow rates, can be found by Equalized flow rate:

New flow rates = Total discharge volume/24

$$= \text{original flow rate} \times \frac{\text{working hours}}{24}$$

Example_4: A factory and WWT plant discharges in to a river. Based on the below table; determine TDS after junction

	River (before mixing point)	Wastewater Treatment Plant	Factory
Flow rate (m^3/h)	20,000	3,100	800
Working hours daily		24	6
COD (mg/L)	14	70	420
TDS (mg/L)	360	420	2,600

1) Within and out of working hours of factory
2) Using the equalization tank in factory

Solution of example-4:

	River (before mixing point)	Wastewater Treatment Plant	Factory
Flow rate (m^3/h)	20,000	3,100	800
Working hours daily		24	6
COD (mg/L)	14	70	420
TDS (mg/L)	360	420	2,600

1.1) Within working hours of factory

TDS=[20,000 * 360 + 3100 * 420 + 800 * 2600]/
[20,000 + 3,100 + 800] = **442.8 mg/L**

1.2) Out of working hours of factory

TDS= [20,000 * 360 + 3,100 * 420]/
[20,000 + 3100] = **368.1 mg/L**

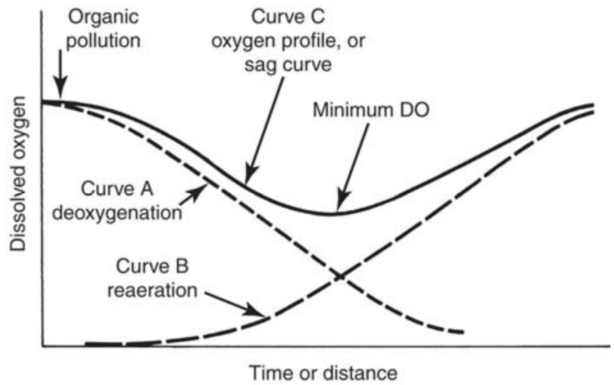
2) Using equalization tank

TDS = [20,000*360 + 3100*420 + 800*2600*6/24] /
[20000 + 3100 + 200] = **387.2 mg/L**

Dissolved Oxygen Profile

- When sewage is discharged into a stream, dissolved oxygen is utilized by microorganisms as they metabolize and decompose organic substances from the wastewater.

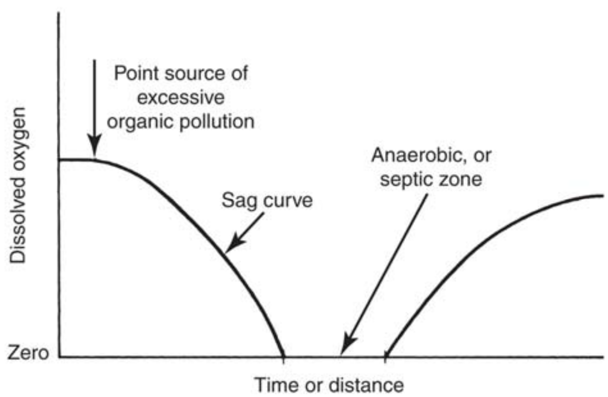
The minimum dissolved oxygen content in the stream occur when the rate of reaeration equals the rate of deoxygenation.



The **oxygen sag curve** shows the effect of organic pollution on the DO levels in a stream or river. After the organics decompose, surface reaeration will restore the original water quality. This is called **stream self-purification**.

21

Dissolved Oxygen Profile

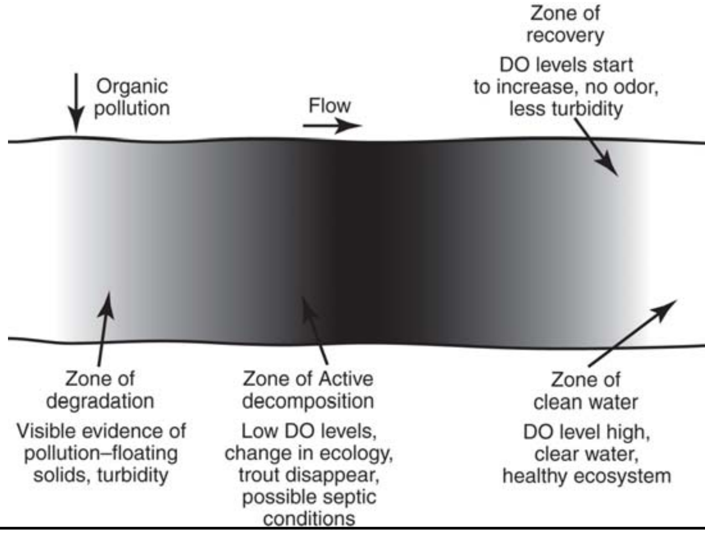


Under **heavy loads of pollution**, the DO level may drop to zero. This results in **hateful odors** and very unsightly conditions in the water. With additional time and distance downstream, the water will eventually be reaerated and water quality will be restored.

22

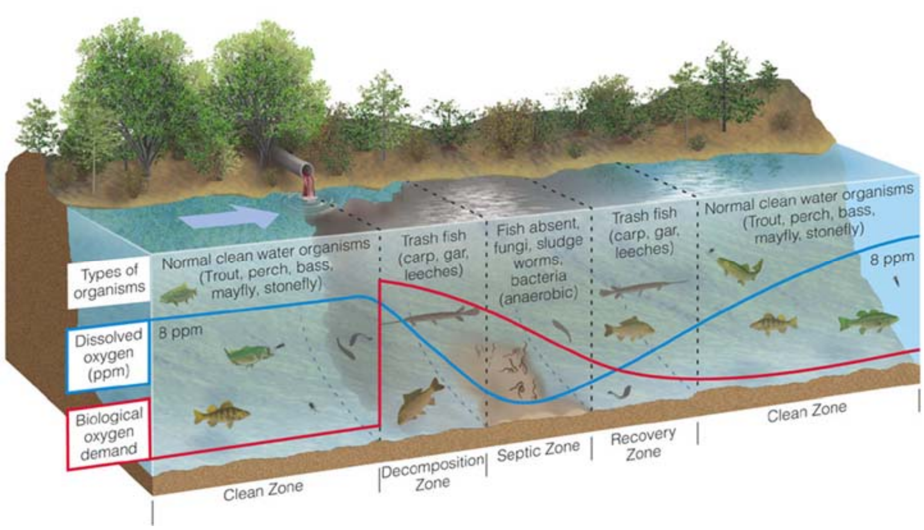
Zones of Pollution

- Most streams that are polluted by a point source of biodegradable organic substances can be described and evaluated in terms of **four distinct zones**.



Zones of Pollution

- Most streams that are polluted by a point source of biodegradable organic substances can be described and evaluated in terms of **four distinct zones**.

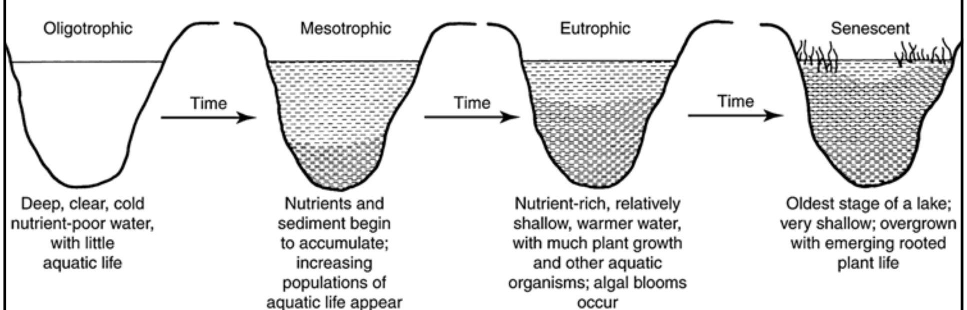


4. Lake Pollution

- Water in lakes is not moving much and is detained for a relatively long period of time, that mean self-purification will requires more time not like river and stream.
- In lakes, water quality may be more **dependent on plant nutrients** than on organics from sewage.
- Phosphorus and nitrogen are the most critical plant nutrients.
- When pollutants containing phosphorus and nitrogen compounds accumulate in a lake, rooted aquatic plants and free-floating algae may grow plentifully.
- The algae and aquatic weeds eventually die and settle to the bottom of the lake, where they are decomposed by bacteria and protozoa.
- This exerts an oxygen demand on the water and may deplete the DO in parts of the lake.

25

- The process of **nutrient enrichment** and gradual accumulation in a lake, as just described, is a natural process. It is called **eutrophication** and can be thought of as an inevitable an continual aging of the lake.



- Four stages in the life of a lake. All lakes go through **a natural aging process called eutrophication**. **Human activity often accelerates this process**.
- **Cultural** (or anthropogenic) **eutrophication** is the acceleration of the natural aging process due to human activity.

26

5. Groundwater Pollution

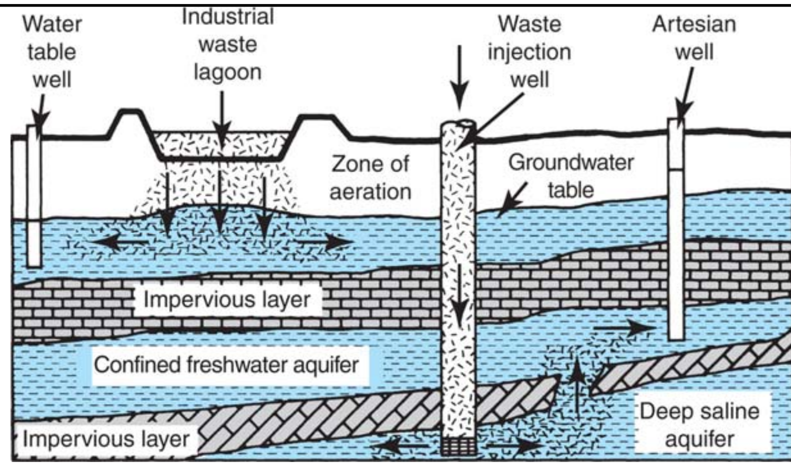
- Groundwater is usually of **excellent quality**. This is primarily because of the **natural filtration** that occurs in the layers of soil through which the water slowly moves underground.
- An increasing number of contaminated groundwater in certain locations have been reported.
- The contaminants come from many different sources and include a variety of materials, most notably **synthetic organic chemicals**.
- Of all types of water pollution, this synthetic organic chemicals is perhaps the most insidious because **at low concentrations the contaminants rarely impart any noticeable taste or odor to drinking water**.

27

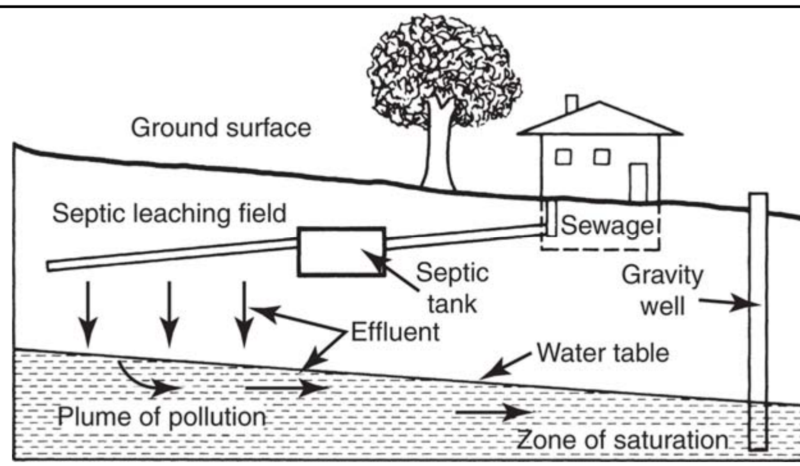
Sources of Groundwater Contamination:

1. Improper disposal of wastes, such as unlined landfills or industrial sewage lagoons.
2. Accidental spills of hazardous substances, especially from industrial activities.
3. Petroleum products leaking from old underground storage tanks (USTs).
4. Mining and petroleum production, especially from hydraulic fracturing technology.
5. Subsurface sewage disposal systems.
6. Agricultural activities.
7. Saltwater Intrusion.

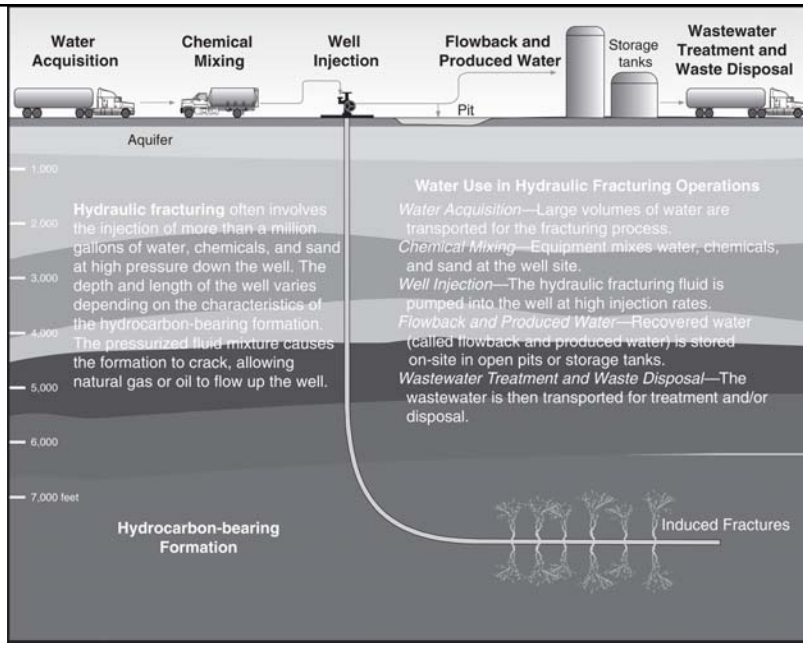
28



- Diagram showing two sources of ground water pollution from industrial waste disposal a **leaky surface impoundment or lagoon** and **deep well wastewater injection**.
- The arrows indicate the direction of flow of the pollutants.
- A **bottom liner for the lagoon** and thorough geological exploration of the saline aquifer can help prevent the pollution.



- Groundwater can be polluted from **on-site sewage disposal systems**.
- Wells located downhill from septic absorption fields are susceptible to contamination.



Water cycle in hydraulic fracturing. (Courtesy of the U.S. EPA)

31

- **Natural purification of chemically contaminated** groundwater can **take decades** and perhaps centuries, and cleanup efforts are sometimes much too expensive to be practical.
- If an **aquifer that supplies drinking water is polluted**, it may be necessary to abandon the contaminated well(s) and drill new ones some distance away.
- The best way to **control groundwater pollution** is to **prevent** it from occurring in the first place.
- **Laws** related to solid and hazardous waste disposal significantly reduce new contamination.

32

6. Ocean Pollution

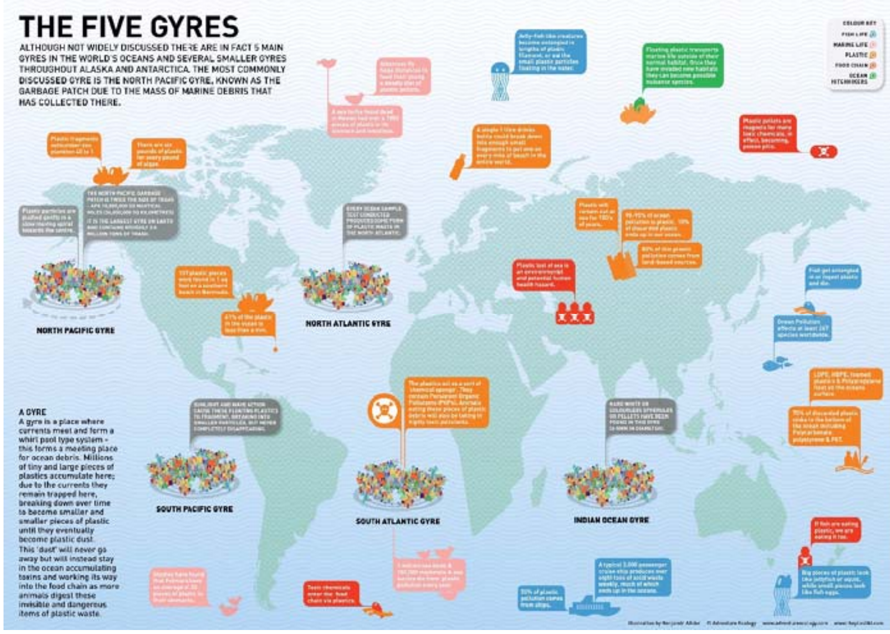
- Ocean water is naturally saline (salty), containing about 3.5% dissolved solids (35 grams per liter, or 35,000 mg/L).
- Despite the ocean provide a tremendous reservoir for dilution of pollution, the ocean volume is not infinite, and its capacity to assimilate pollution in **estuaries** and other sensitive **coastal zones** between ocean and land is finite and limited
- In some **coastal areas**, excessive chemical nutrients from sewage and dispersed agricultural runoff can cause seasonal formations of **hypoxic areas**, in which DO levels drop so low.
- Problems related to degradation of the ocean waters are global in scope.

33

Sources of ocean pollution:

1. Diffusion of sewage in Seawater.
   – Treated sewage effluent from cities and towns is discharged directly into the ocean in many coastal areas.
2. Ocean dumping of sludge
   – Used in the past but now is banned
3. Oil spills
   – Accidental discharges of oil into ocean and bay waters can cause serious ecological damage to marine system.
4. Floating plastic rubbish
   – Use of biodegradable plastics, as well as an emphasis on waste recycling and waste minimization can help to mitigate this problem.

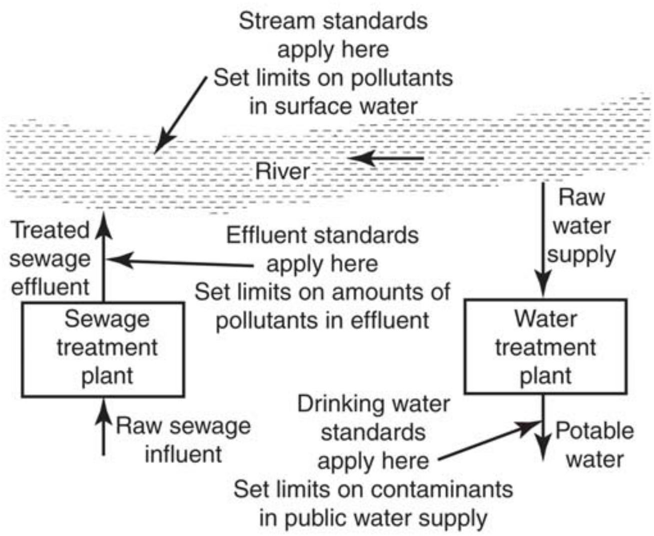
34



Plastic debris has been found by oceanographers to accumulate primarily in five regions

Water Quality Standard

- Standards were established to **limit the amount of pollutants discharged** into streams, lakes, and coastal waters
- Water quality standards are **limits on the amount of physical, chemical, or microbiological impurities allowed in water that is intended for a particular use**.
- There are three different types of water quality standards:
  1. Stream standards
     - classification of surface waters on the basis of their beneficial use.
  2. Effluent standards.
  3. Drinking water standards.



Three different types of **water quality standards are enforced by the regulatory agencies to protect public health and environment**.

Saudi Arabian Drinking Water Standards (bottled water)

(Ministry of Municipal and Rural Affair, 1426)

مواصفات وزارة الشؤون البلدية والقروية لمياه الشرب المعبأة (١٤٢٦هـ – ٢٠٠٥م)

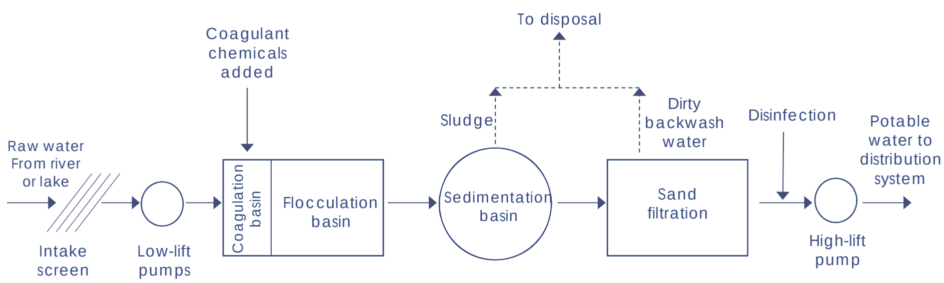
Parameter	المواصفة	نوع التحليل	النوع
Color	15 وحدة	اللون	الخصائص الطبيعية
Turbidity	5 حدات	العكارة	
Taste	مقبول	الطعم	
Odor	عديم الرائحة	الرائحة	
pH	6.5 - 8.5	الرقم الهيدروجيني	
TDS	700	الإملاح الكلية الذائبة	الخصائص الكيميائية
Total hardness(2)	300	العسر الكلي	
Magnesium	30	المغنسيوم	
Calcium	75	الكالسيوم	
Sodium	200	الصوديوم	
Sulfate	250	الكبريتات	
Chloride	250	الكلوريدات	
Aluminum	0.2	الالمنيوم	
Iron	0.3	الحديد	
Copper	1	النحاس	
Zinc	5	الزنك (الخارصين)	
Manganese	0.05	المنجنيز	
Arsenic	0.05	الزرنيخ	
Cadmium	0.01	الكادميوم	
Mercury	0.001	الزئبق	
Selenium	0.01	السلينيوم	
Chrome	0.05	الكروم	
Nitrate	10	النترات	
Nitrite	0.005	النتريت	
Fluoride	0.8	الفلورايد	
Lead	0.05	الرصاص	
Alpha Radiation	0.1 pCi/L	أشعة ألفا	الخصائص الإشعاعية
Beta Radiation	1 pCi/L	أشعة بيتا	
Fecal Coliform	Zero	بكتريا القولون	الخصائص الميكروبية
Bacteria (for 24 hr)	50 cell/mL	بكتريا (خلال ٢٤ ساعة)	
Bacteria (for 72 hr)	100 cell/mL	بكتريا (خلال ٧٢ ساعة)	

Note:
(1) All units are in mg/L, except for stated one.
(2) Calculated as calcium carbonate

Examples of Water Pollution Control

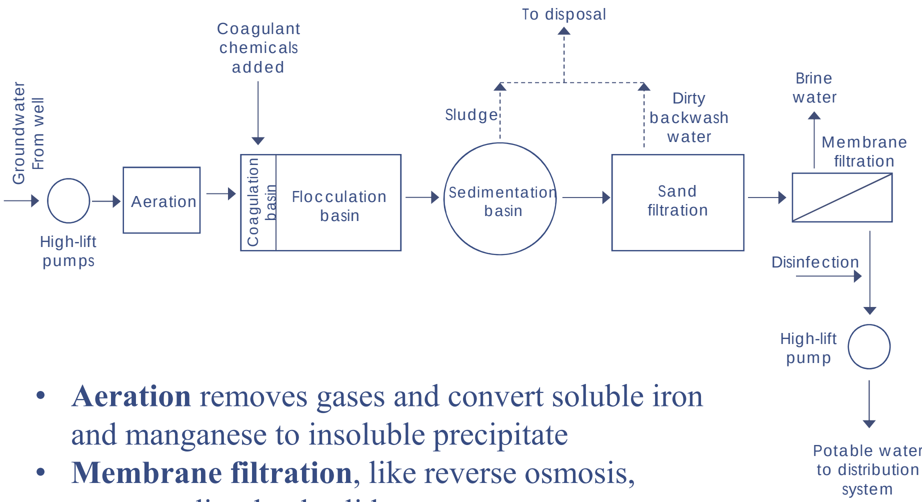
- Water Treatment Plant
- Wastewater Treatment Plant
- Oil Spill treatment methods
- Produced Water Treatment

Flow diagram of a typical Surface Water treatment plant



- **Screens** keep debris and large objects out of the plant
- **Low-pressure pumps** lift the water to the coagulation tank
- **Coagulation-flocculation, sedimentation, and sand filtration** remove turbidly, suspended solids, some of dissolved solids, and clarify the water (**Clarifications**)
- **Disinfection** destroys pathogenic organisms
- **High-pressure pumps** deliver potable water to the consumers

Flow diagram of a typical Groundwater treatment plant

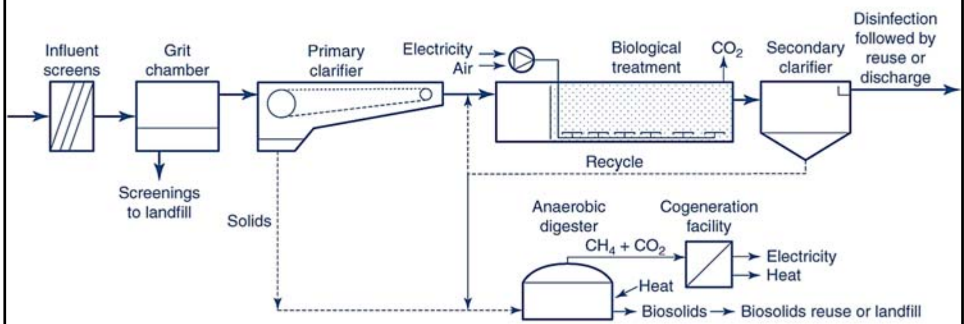


- **Aeration** removes gases and convert soluble iron and manganese to insoluble precipitate
- **Membrane filtration**, like reverse osmosis, removes dissolved solids

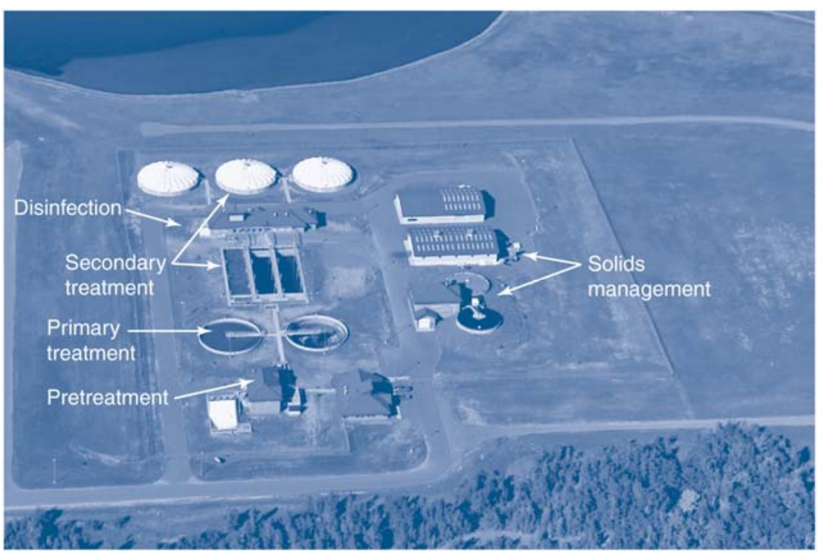
41

Reverse Osmosis (RO) units

Schematic of conventional Wastewater Treatment Plant
(Biological Treatment)



43



Aerial view of Wastewater Treatment Plant

Concentration of major constituents found in average-strength wastewater

Constituent	Average Concentration	Comments
Biochemical oxygen demand (BOD)	200 mg/L	Oxygen-demanding materials can deplete the oxygen content of receiving waters.
Suspended solids	240 mg/L (total solids typically 800 mg/L)	Cause water to be turbid; may contain organic matter and thus contribute to BOD; may contain other pollutants or pathogens. Organic solids can be anaerobically digested to produce energy.
Pathogens	3 million coliforms per 100 mL	Disease-causing microorganisms usually associated with fecal matter.
Nutrients such as nitrogen and phosphorus	Total nitrogen: 35 mg N/L Inorganic nitrogen: 15 mg N/L Total phosphorus: 10 mg P/L	Can accelerate growth of aquatic plants, contribute to eutrophication; ammonia is toxic to aquatic life, can contribute to NBOD. Value as crop fertilizer during water reuse.
Toxic chemicals	Variable	Heavy metals such as mercury, cadmium, and chromium; organic chemicals such as pesticides, solvents, fuel products.
Emerging chemicals of concern	Unknown or variable	Pharmaceuticals, caffeine, surfactants, fragrances, perfumes, other endocrine-disrupting chemicals.

Oil Spill


Chronicle / Kurt Rogers

- The oil may be a variety of materials, including crude oil, refined petroleum products (such as gasoline or diesel fuel) or by-products.
- Spills take months or even years to clean up

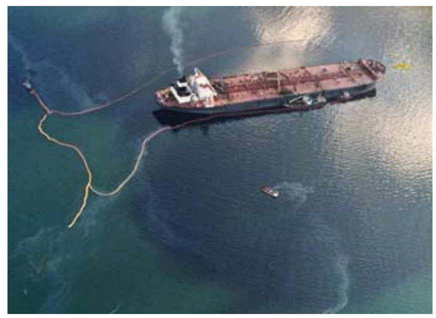
Methods for Cleaning up Oil spills

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.

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** and **vacuum systems**.



3) Sorbents

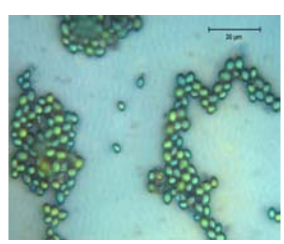
Sorbent booms and barriers are used to absorb a moving oil slick. They only work well when a slick is thin, because once their surfaces are saturated, they cannot absorb anymore.

4) In-situ Burning

Through controlled burning of the oil can effectively remove the oil slick. This method is called in-situ burning.

5) Bioremediation

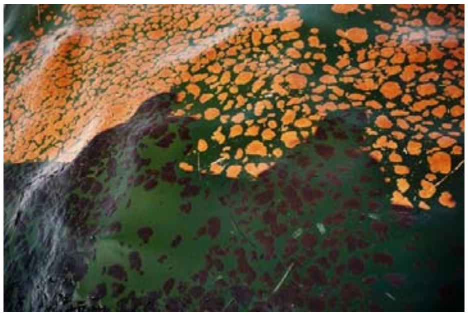
Oil, like many natural substances, will biodegrade over a period of time into simple compounds such as carbon dioxide, water and biomass. Bioremediation is the term used to describe a **range of processes, which can be used to accelerate natural biodegradation**.



48

6) Manual Cleanup
The other best way to clean up oil once it has hit the shore is by manual cleanup.

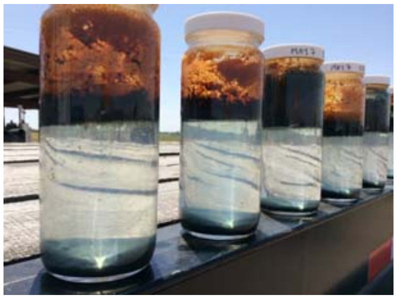
7) Dispersants
Dispersants are chemicals, which have components of surface-active agents called **surfactants**. The dispersants aids in the **breaking up of the oil slick** into smaller droplets.



49

Produced Water

- Is a byproduct water along with the oil and gas production.
- Oil wells have more produced water than gas wells
- Waterflooding (or water injection) is a technique that often used to increase the production of oil wells.



50

Department of Civil Engineering
College of Engineering
King Saud University

GE 302 – Industry and the Environment
Topic 5

Air Pollution and Control

- Air is necessary for the survival of **all higher forms** of life on earth. On the average, a person needs at least 13 kg of air every day to live, but only about 1.4 kg of water and 0.7 kg of food.
- Scientific studies have demonstrated that over the long term, the **standard of health for people** living and working in **urban areas** is lower than that for populations in **rural areas**, where air pollution is much less severe.
- There is much scientific evidence of a distinct relationship between generally **dirty air** and a higher incidence of **respiratory diseases**, including lung cancer.
- There is also compelling evidence that air pollution has a **significant** and lasting worldwide (global) impact on the **Earth's climate**.

Atmospheric Layers

Atmospheric layers is divided into **5 layers,** based on increase or decrease of temperature with altitude.

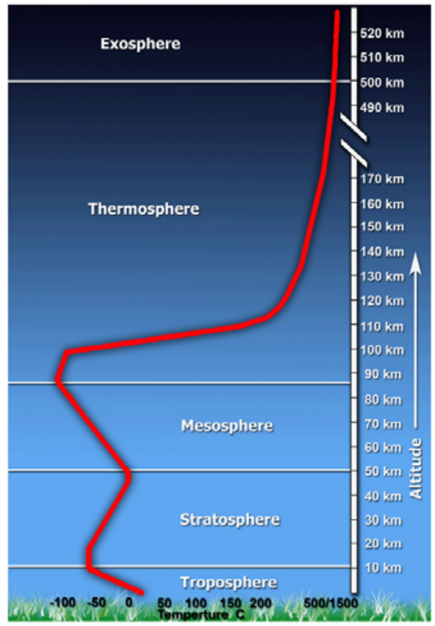
Exosphere

Thermosphere

Mesosphere

Stratosphere

Troposphere



Composition of the Atmosphere

- **Dry air in the troposphere** (the lowermost atmospheric layer) is a mixture of molecular of:
  - **78 % Nitrogen** by volume
  - **21 % Oxygen** by volume
  - **1 % Other gases**: argon(about 0.9 %), carbon dioxide, methane, and water vapor.
- The relative amount or concentrations of gases in air can be expressed in terms of **parts per million** (ppm) and in terms of **percentage**.
- For example, since **1 % = 10,000 ppm**, an oxygen level of 21 % in air can also be expressed as 210,000 ppm.
- The concentration of carbon dioxide (CO_2) in the atmosphere, now close to 0.04%, may be more conveniently expressed as 400 ppm.

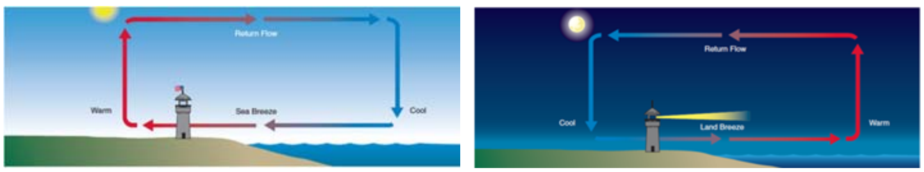
- The troposphere, contains about **80 % of the total air mass**.
- It is in this relatively **thin layer of air** that oxygen-dependent **life is sustained**, **clouds** are formed, **weather** patterns develop, and most **air pollution** problems occur.
- The **density of air** (about 1.23 kg/m^3 at sea level) decreases significantly with an increase in altitude.
- **Troposphere** layer is about on average 12 km depth
- Troposphere is deeper in the tropics, up to 20 km, and shallower near the polar regions, approximately 7 km

Effects of Weather

- Air pollutants are **mixed, dispersed, and diluted** within the troposphere by **movement of air** masses, both **horizontally** and **vertically**.
- **Air movements** and therefore air quality are very dependent on local and regional **weather conditions**.
- Knowledge of horizontal and vertical **circulation patterns of air** is of importance with regard to:
  - **site selection for new industrial plants.**
  - **design of tall stacks or chimneys.**

Horizontal Dispersion of Pollutants

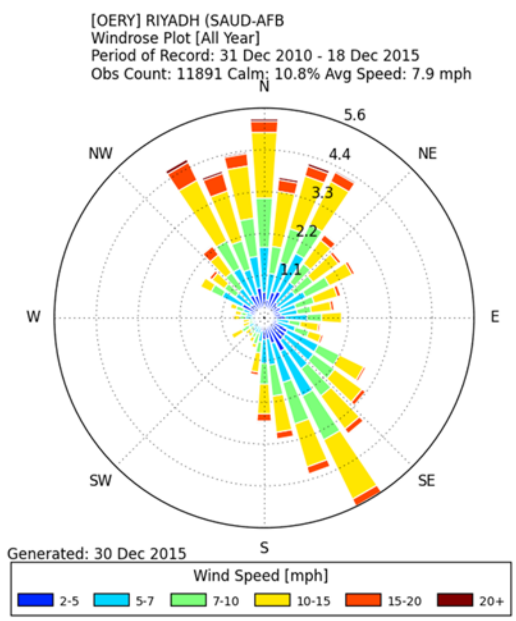
- Horizontal dispersion or spreading of air pollutants depends on **wind speed and direction**.
- Because **soil and rock warm up and cool faster than water**, winds near shorelines are directed toward the water at night and inland during the day.
- In an **urban area**, where steel, concrete, and masonry absorb and hold heat, **a heat island** cover the city at **night**, with a **self-contained circulation pattern** from which pollutants cannot readily escape.



Sea breeze and **land breeze** wind circulation pattern

Wind Rose of Riyadh

- The wind rose indicates the **frequency with which the wind blows from a given direction** (N - North, S - South, E - East, W - West).
- For example, a wedge directed straight up (N) and extending 4 rings means that the wind blows from the North 4% of the time



8

Vertical Dispersion of Pollutants

- Vertical mixing of air and dispersion of pollutants depends on the kind of **atmospheric stability** prevailing at any given time.
- The atmosphere is considered to be **stable** when there is **little or no vertical movement** of air masses and therefore little or no mixing and dispersion of pollutants in the vertical direction.
- An **unstable atmosphere**, on the other hand, is one in which the **air moves naturally in a vertical direction**, increasing mixing and dispersion of the pollutants.
- With regard to local or regional **air quality**, a condition of **atmospheric instability** is preferable to a stable condition.

Vertical Dispersion of Pollutants

- **Air stability** depends on the **rate of change of air temperature with altitude**, called the **temperature gradient**.
- The rate at which **air temperature drops** with increasing altitude in the troposphere is called the **environmental lapse rate**.
- The **dry adiabatic lapse rate** is the lapse rate of a dry mass of air which expands and cools as it rises. This rate is typically -10 °C per 1 km (or **-1 °C per 100 m**).
- Dry adiabatic lapse rate is **independent** of the **prevailing** atmospheric **temperature gradient** at any given time.

10

Vertical Dispersion of Pollutants

- When the **environmental** lapse rate **exceeds** the **adiabatic lapse rate**, the atmosphere is **unstable** and vertical mixing of air masses will occur
- A lapse rate characterized by an increase in air temperature with increasing altitude, called a **temperature inversion**, results in an extremely stable condition.
  - –This prevents the upward mixing of pollutants and a major cause of severe air pollution episodes.

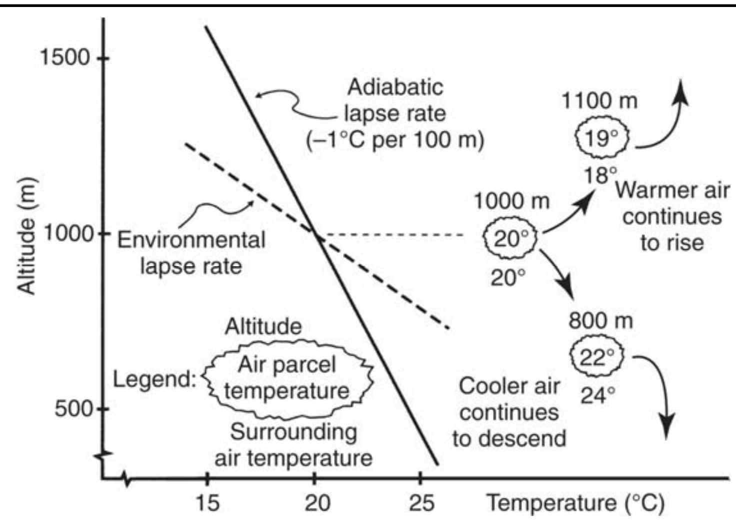
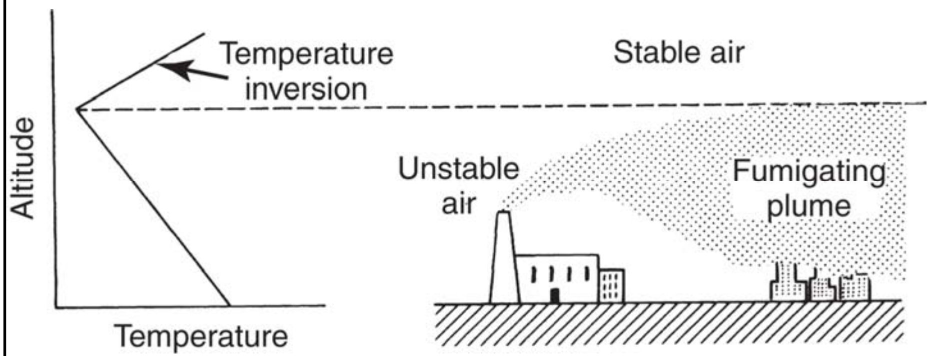
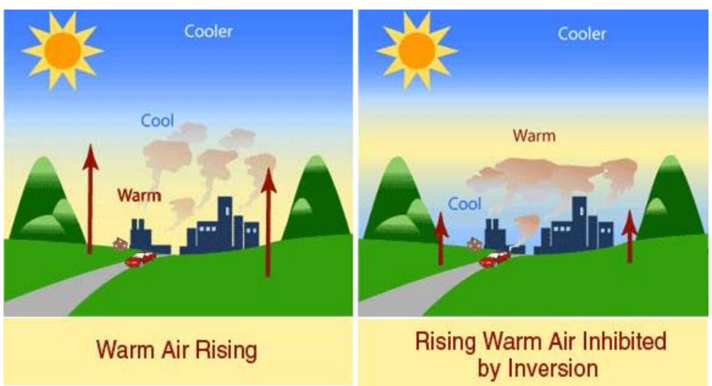


Illustration of **unstable** atmospheric conditions, when the **environmental lapse rate** (e.g., **–2° per 100 m**) **exceeds the adiabatic** lapse rate. In this example, buoyant forces keep the air parcels moving in a vertical direction.



When a **temperature inversion** begins above the ground because of local weather conditions, **it acts as ceiling that prevents further vertical mixing and traps pollutants below it**

13



Temperature Inversion

- **Trapping of pollutants** below the inversion, allowing them to build up.
- If the **sky** is very **hazy**, or is **sunsets are very red**, there is likely an inversion somewhere in the lower atmosphere.
- This happens more frequently in **high pressure zones**, where the gradual sinking of air in the high pressure dome typically causes an inversion to form at the base of a sinking layer of air.

14

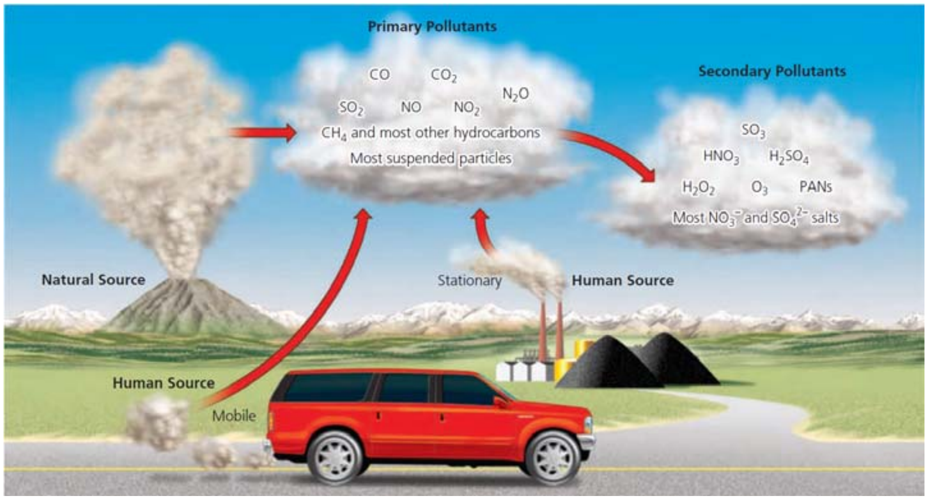
Type of Air Pollution

- Air pollution may be simply defined as the presence of **certain substances** in the air in **high** enough **concentrations** and for **long** enough **durations** to cause undesirable effects.
  - "Certain substances" may be any gas, liquid, or solid
- Based on the sources, air pollutants involves:
  - **Primary pollutants**: are **emitted directly** into the air from a specific source, such as a power plant stack.
  - **Secondary pollutants**: are not emitted directly from a source but are **formed in the atmosphere** by complex chemical reactions involving the primary pollutants and sunlight (like ozone).
- Air pollution is **anthropogenic**, that is, caused by **human activities**. But air pollution may also result from **natural causes**.

15

- The sources of primary air pollutants are either **mobile** (e.g., automobiles) or **stationary** (e.g., coal-fired electric power generating stations).
- **Criteria air pollutants** that are regulated in many countries are:
  - **Sulfur dioxide (SO_2)**
  - **Nitrogen oxides (NO_x)**
  - **Carbon monoxide (CO)**
  - **Particulates matter (PM)**
  - **Lead (Pb)**
  - **Ozone (O_3)**
- All the criteria pollutants tend to **harm human health**, diminish environmental quality, **and damage property**.

16

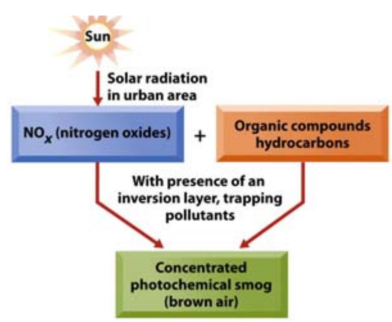


Human inputs of air pollutants come from **mobile sources** (such as cars) and **stationary sources** (such as industrial, power, and cement plants). Some **primary air pollutants** react with one another and with other chemicals in the air to form **secondary air pollutants**.

17

- **Sulfur dioxide**, a colorless gas with a sharp, choking odor,
  - comes primarily from fossil fuel combustion at electric power plants.
  - It is one of the causes of acid rain.
- **Nitrogen dioxide**, a pungent irritating gas
  - it is also caused by combustion of fossil fuels
  - can react in sunlight with hydrocarbons to form **photochemical smog**.

Photochemical smog, Santiago, Chile



- **Carbon monoxide** is a colorless and odorless gas
  - –**CO** is a product of incomplete combustion, is the most abundant of the criteria pollutants
  - –it comes largely from **highway vehicle emissions and residential heating systems**.
  - –It reduces the ability of blood to transfer oxygen to body cells, and at high concentrations, it can be acutely toxic.

- **Particulates** are extremely small fragments of solid or liquid droplets suspended in air.
  - –Major sources of particulates include industrial materials handling processes, coal- and oil-burning power plants, residential heating systems, and highway vehicles.
  - –Particulates that penetrate deep into the lungs are harmful, and certain particulates can be toxic or carcinogenic (cause cancer)

- **Particulates**
  - –consider that the average human hair is about 65 µm in diameter
  - –PM smaller than 1 µm tend to remain suspended in the atmosphere indefinitely, whereas those larger than 1 µm can eventually settle out.
  - –The particulate materials of most concern with regard to adverse effects on human health are **equal to or less than 10 µm** in size and are referred to as **PM10**
  - –Fine particles, those with diameters **equal to or smaller than 2.5 µm** (**PM2.5**) are of special concern because they are more likely to penetrate deep into the lungs when inhaled.

- **Lead** fumes, emitted primarily by petroleum refining and smelting operations, are also toxic.

- **Ozone**, a secondary pollutant (i.e., not emitted directly but formed in the atmosphere), is an irritating gas and also a key component of photochemical smog

21

Hazardous Air Pollutants

- Air pollutants associated with **certain specific sources**, and that pose an **immediate threat to human health**, are called **air toxics** or **hazardous air pollutants** (HAPs) examples are:
  - **Asbestos**
  - **Benzene**
  - **Beryllium**
  - **Mercury**
  - **Vinyl chloride**
  - **Radionuclides** (radioactive air pollutants)

22

Gases Concentration Measurement

- Concentration of air gaseous pollutants in air are mostly expressed in volumetric terms

$$\frac{\text{1 volume of gaseous pollutant}}{10^6 \text{ volume of air}} = \mathbf{1\ ppm} \text{ (by volume)}$$

- Sometimes concentrations are expressed as mass per unit volume, such as **μg/m3** or **mg/m3**.
- The relationship between ppm and mg/m3 depends on the **pressure, temperature,** and **molecular weight** (MW) of the pollutant.
- The ideal gas law helps us establish that relationship

Conversion between ppm and mg/m^3

In general, the conversion from ppm to mg/m^3 is given by:

$$\mathbf{mg/m^3} = \frac{\mathbf{ppm \times MW}}{\mathbf{22.4}} \times \frac{\mathbf{273.15\ K}}{\mathbf{T\ (K)}} \times \frac{\mathbf{P\ (atm)}}{\mathbf{1\ atm}}$$

Where:

MW = molecular weight of the compound (g/mol)

T = absolute temperature **(K) = °C + 273.15**

P = absolute pressure (atm) = mmHg/760

$$\mathbf{mg/m^3} = \frac{\mathbf{ppm \times MW}}{\mathbf{22.414}} \quad (\mathbf{at\ 0\ ℃\ and\ 1\ atm})$$

Example_1: The Air Quality Standard for carbon monoxide is 9.0 ppm. Express this standard as a percent by volume and in mg/m^3 at 1 atm and 25 °C.

Solution:

- Within a million volumes of this air there are 9.0 volumes of **CO,** no matter what the temperature or pressure (advantage of the ppm units)

$$\% \ \mathrm{CO} = \frac{9}{10^6} \times 100 \ \% = 0.0009 \ \%$$

- To find the concentration in mg/m^3, we need the molecular weight of **CO**, which is = 12 +16 = 28

$$\mathbf{mg/m^3} = \frac{\mathbf{ppm \times MW}}{\mathbf{22.4}} \times \frac{\mathbf{273.15\ K}}{\mathbf{T\ (K)}} \times \frac{\mathbf{P\ (atm)}}{\mathbf{1\ atm}}$$

$$\mathbf{mg/m^3} = \frac{\mathbf{9 \times 28}}{\mathbf{22.4}} \times \frac{\mathbf{273.15}}{\mathbf{(25 + 273.15)}} \times \frac{\mathbf{1\ (atm)}}{\mathbf{1\ atm}}$$

$$\mathrm{CO} = 10.3 \ \mathrm{mg/m^3}$$

Example_2: Suppose the exhaust gas from an automobile contains 0.75% by volume of sulfur dioxides (SO_2). Express this concentration in mg/m^3 at 29 °C and 1.0 atm pressure.

Solution:

Homework

Primary and secondary National Ambient Air Quality Standards (NAAQS)

Pollutant	Averaging time	Allowable concentration
$PM_{2.5}$	Annual arithmetic mean	35 $\mu g/m^3$ (primary and secondary)
	24 h	12 $\mu g/m^3$ (primary and secondary)
PM_{10}	24 h	150 $\mu g/m^3$ (primary and secondary)
SO_2	1 h	75 ppb (primary)
	3 h	0.5 ppm (secondary)
CO	8 h	9 ppm (primary)
	1 h	35 ppm (primary)
NO_2	Annual arithmetic mean	53 ppb (primary and secondary)
	1 h	100 ppb (primary)
O_3	8 h	75 ppb (primary and secondary)
Pb	3 mo	0.15 $\mu g/m^3$ (primary and secondary)

Effects of Ambient Air Pollution

- Air pollution is known to have many adverse effects, including those on:
  - –Human health
  - –Building facades and other exposed materials
  - –Vegetation and agricultural crops
  - –Animals and aquatic habitat
  - –The climate of Earth as a whole
- Generally, air pollution is most harmful to the **elderly** and to the **baby**.

- Major health effects are categorized as being either:
  - **Acute**

    short-lasting, but severe, and may even result in death
  - **Chronic**

    long-term effects usually include respiratory illnesses such as asthma and perhaps lung cancer
  - **Temporary**

    effects include intermittent periods of eye or throat irritation, coughing, chest pain, ...
- Typical effects of sulfur dioxide, oxides of nitrogen, and ozone include eye and throat irritation, coughing, and chest pain.
- A **threshold level** for a given pollutant is a minimum level below which there will be no health effects.

Worldwide Air Quality Issues

- Air pollution problems are not necessarily confined to a local or regional scale. Atmospheric circulation can transport certain pollutants far away from their point of origin, expanding air pollution to continental or global scales
- **Worldwide air quality issues**:
  - **Acid rain**
  - **Global warming**
  - **Ozone layer depletion**

Acid Rain

- acid rain, for example, occurs largely on a regional and a continental scale. It has killed fish and plant life in thousands of lakes in Europe, China, Canada, and the northeast United States.
- It also causes deterioration of metals, concrete, painted surfaces, and other exposed objects.
- Acid rain is caused by **emission of sulfur and nitrogen oxides**, mostly from electric power plants.

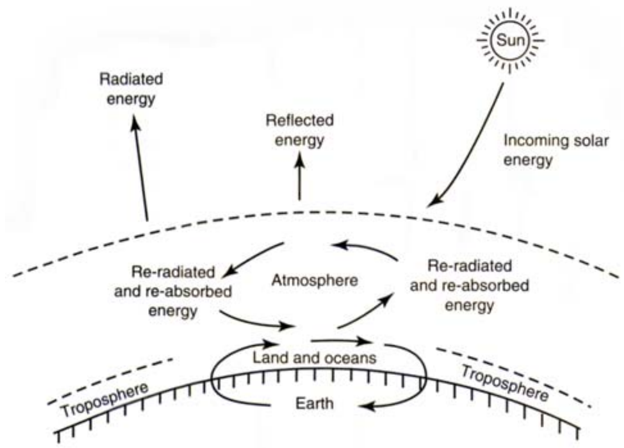
31

Global Warming

- The current trend of increasing average temperatures is believed by most scientists to be caused by the **accumulation of carbon dioxide** and other greenhouse gases emitted as a result of human activities.
- Global warming may lead to <u>melting of glaciers</u> and a <u>rise in sea levels</u>, as well as adversely affecting ecosystems in some parts of the world

32

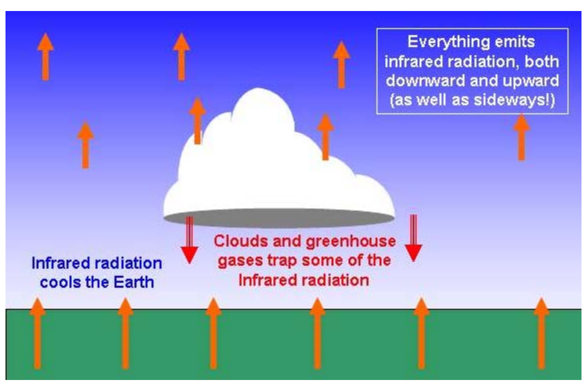
Global Warming



The amount of incoming energy from the sun is in equilibrium with the energy radiated and reflected back into space. **The atmosphere acts as a "blanket" that regulates average temperatures** at the Earth's surface. The "thicker" the blanket (i.e., the more "greenhouse gases" in the atmosphere), the warmer is the temperature in the lower atmosphere and Earth's surface.

33

Infrared Radiation (Heat Radiation)

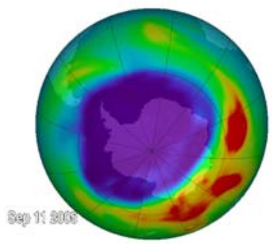


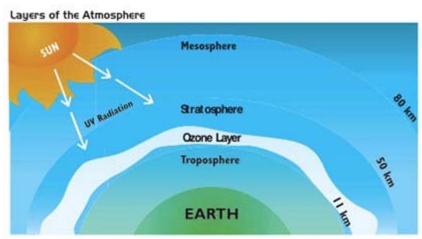
- Infrared (IR) radiation is just as important to the Earth's weather and climate as sunlight is.
- This is because, for all of the sunlight that the Earth absorbs, an equal amount of IR radiation must travel from the Earth back to outer space.
- If this was not the case, there would be global warming or global cooling.

34

Ozone Layer Depletion

- **Stratospheric ozone** is important because it blocks harmful UV rays from the sun.
- But those ozone levels have been dropping, largely due to the presence of **non biodegradable organic chemicals** such as **chlorofluorocarbons (CFC)** from aerosol cans, refrigerants, and industrial solvents.
- CFC production and use is now banned in many counties.





Air Quality Index

- To be able to **provide the public with timely**, easy-to-understand **information about outdoor air quality** and to evaluate national air quality trends, the Environmental Protection Agency (EPA) publishes a daily Air Quality Index or **AQI**
- EPA uses 5 Major air pollutants to define AQI.
  - Ground level ozone
  - Particulate matter
  - CO
  - SO_2
  - NO_2

Air Quality Index (AQI) Values	Levels of Health Concern
0 to 50	Good
51-100	Moderate
101-150	Unhealthy for Sensitive Groups
151-200	Unhealthy
201-300	Very Unhealthy
301 to 500	Hazardous

Air Quality Index (AQI)

Category and Range

Category	AQI	8-hr O_3 (ppm)	1-hr O_3 (ppm)	24-hr $PM_{2.5}$ (µg/m³)	24-hr PM_{10} (µg/m³)	8-hr CO (ppm)	24-hr SO_2 (ppm)
Good	0 – 50	0.000 – 0.064	—	0 – 15.4	0 – 54	0 – 4.4	0.000 – 0.034
Moderate	51 - **100**	0.065 – 0.084	—	15.5 – 40.4	55 – 154	4.5 – 9.4	0.035 – 0.144
Unhealthy for sensitive	101 - 150	0.085 – 0.104	0.125 – 0.164	40.5 – 65.4	155 – 254	9.5 – 12.4	0.145 – 0.224
Unhealthy	151 - 200	0.105 – 0.124	0.165 – 0.204	65.5 – 150.4	255 – 354	12.5 – 15.4	0.225 – 0.304
Very unhealthy	201 - 300	0.125 – 0.374	0.205 – 0.404	150.5 – 250.4	355 – 424	15.5 – 30.4	0.305 – 0.604
hazardous	301 - 400	Use 1-hr	0.405 – 0.504	250.5 – 350.4	425 – 504	30.5 – 40.4	0.605 – 0.804
hazardous	401 - 500	Use 1-hr	0.505 – 0.604	350.5 – 500.4	505 – 604	40.5 – 50.4	0.805 – 1.004

The **most significant number on the AQI scale is 100**, since this number corresponds to the standards established under the Clean Air Act for each pollutant.

37

Example_3:

What AQI descriptor (good, moderate, etc.) should be reported for air quality on the following day?

Pollutant	Concentration
O_3, 1-hr (ppm)	0.15
CO, 8-hr (ppm)	12
$PM_{2.5}$, 24-hr (µg/m3)	130
PM_{10}, 24-hr (µg/m3)	180
SO_2, 24-hr (ppm)	0.12

Solution:

From AQI table:

AQI 151-200 triggered by PM2.5, **Unhealthy**

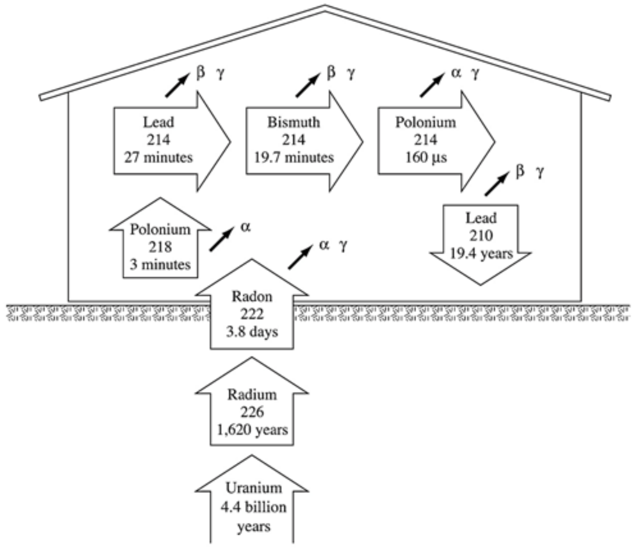
38

Indoor Air Quality

- Indoor air quality (IAQ) is important because people generally spend most of their time indoors.
- Indoor air contaminants include:
  - **combustion products** (especially tobacco smoke)
  - radon
  - asbestos
  - formaldehyde
  - lead
  - biological substances
- **Environmental tobacco smoke** (**ETS**), which contains more than 40 carcinogenic compounds, causes thousands of lung cancer deaths each year in nonsmoking adults

Indoor Air Quality

- **Radon**, a naturally occurring colorless, odorless, radioactive gas, can enter buildings through porous soil and rock fissures at basement walls and floors.
  - It can be a cause of lung cancer if inhaled for long periods
- **Asbestos**, a mineral fiber used as insulation and as a fire retardant in buildings. It has been banned from Saudi Arabia.
  - It can cause lung cancer if very small airborne asbestos fibers are inhaled.
- **Formaldehyde**, a colorless gas that comes from certain building materials and household products.
  - can cause eye and throat irritation (and maybe cancer)



Simplified Uranium decay series, with half-lives and emissions. Radon gas that seeps out of soils can decay inside the buildings

41

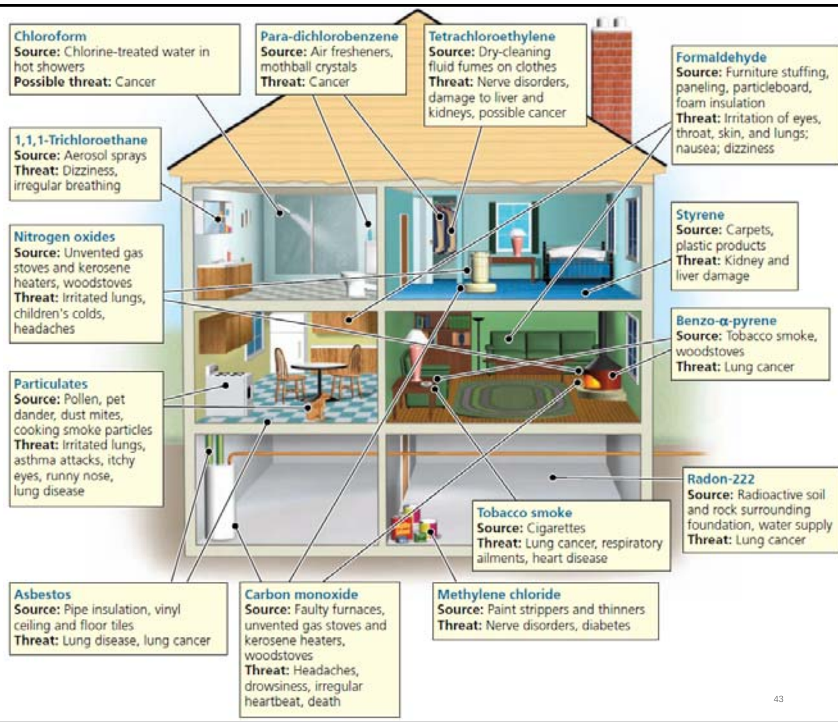
Indoor Air Quality

- Proper **infiltration and ventilation** (air exchange) is necessary to minimize levels of indoor air pollutants.
- Indoor Air Quality (IAQ) is a component of the **LEED green building certification** credits related to indoor environmental quality.

Leadership in **E**nergy and **E**nvironmental **D**esign (LEED)

42

Numerous indoor air pollutants are found in most modern homes



43

Air Pollution Control

- Air pollution control strategies include:
  - –Complete source shutdown
  - –Source location (or air zoning)
  - –Fuel substitution
  - –Process changes
  - –Enforcement of emission standards for specific sources
- Several types of air cleaning devices can trap air pollutants before they are emitted into the atmosphere.

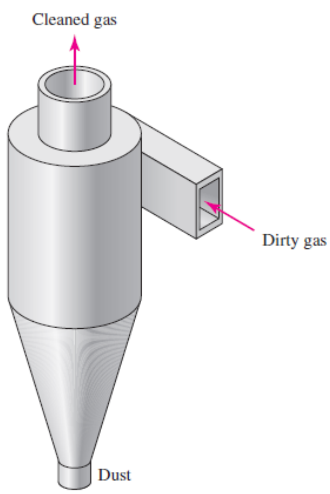
44

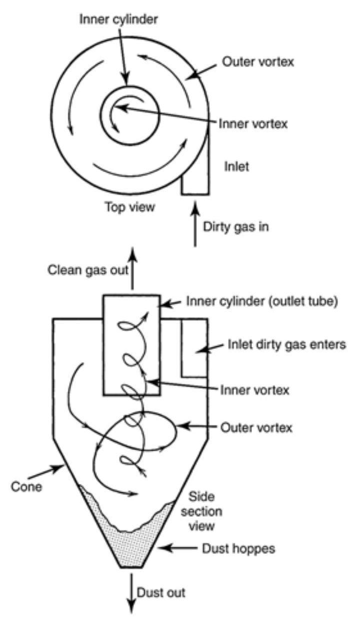
Air Pollution Control

- **Particulate matter control equipment** includes:
  - –Gravity settlers
  - –Cyclones
  - –Electrostatic precipitators
  - –Fabric filters
  - –Wet scrubbers
- The selection of control equipment depends on the range of particulate sizes, flow rates, temperatures of the carrier gas, costs, and other factors.
- One of the most efficient of these devices for **removing suspended particulates is the fabric filter** (or **baghouse**)

45

Particulate matter control equipment

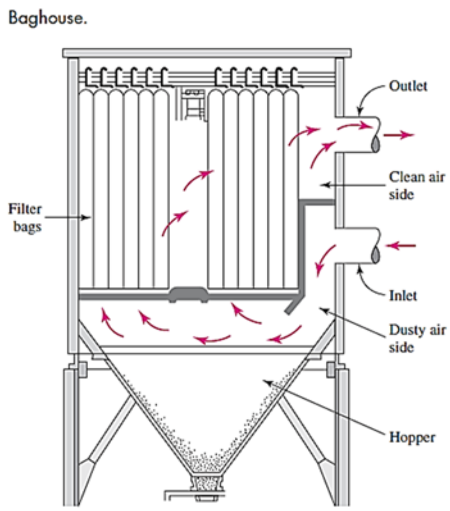




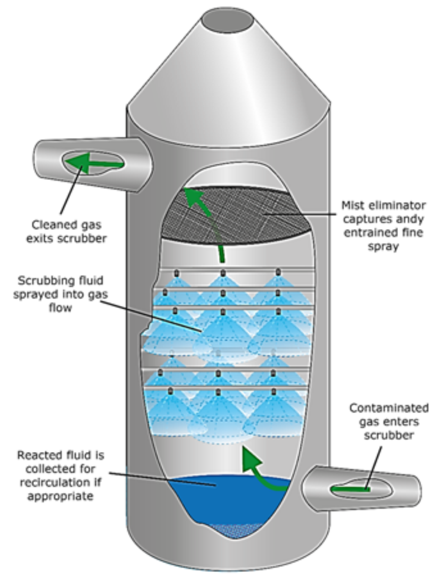
Cyclones

46

Particulate matter control equipment

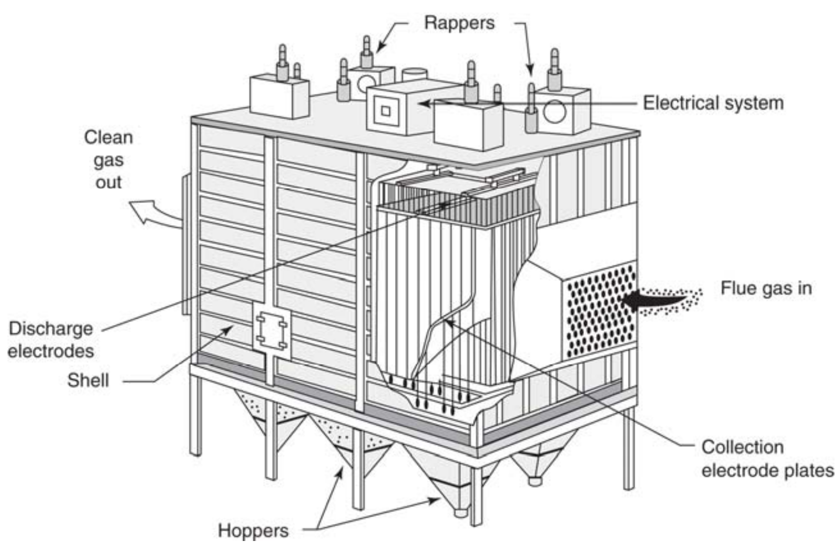


Baghouse (Fabric filters)



Wet scrubbers

Particulate matter control equipment

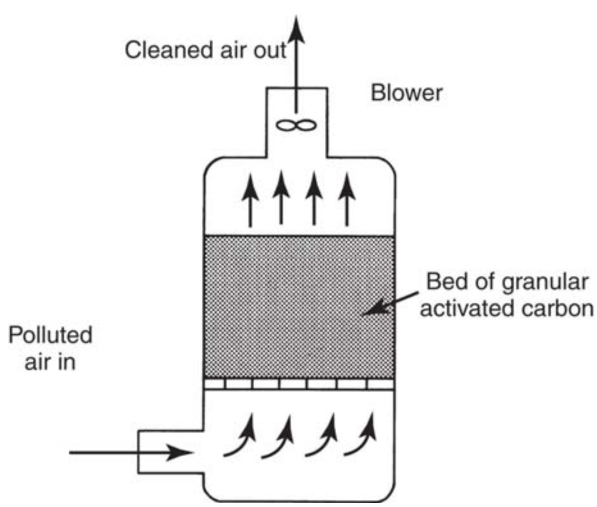


Electrostatic precipitators

Gaseous air pollutants

- Gaseous air pollutants can be controlled using either absorption or adsorption processes.
- **Absorption** involves the transfer of a gaseous pollutant into a contacting liquid.
- **Adsorption** involves attracting and trapping gas molecules onto the surface of a solid (e.g., activated carbon)
- **Wet scrubbers can be used for gas absorption**, as well as packed scrubber towers.
- Emissions from the internal combustion engine, which is a major mobile source of air pollutants, are controlled by positive crankcase ventilation systems and **catalytic converters**.

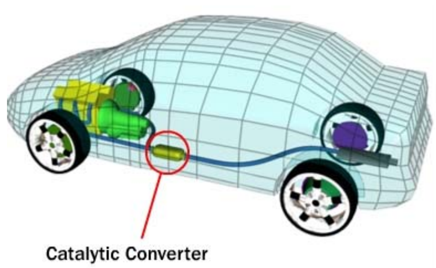
49

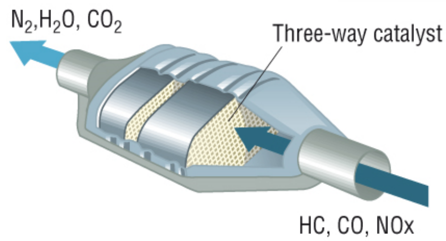


Activated carbon can be used to adsorb certain gaseous air pollutants

50

catalytic converters





Department of Civil Engineering
College of Engineering
King Saud University

GE 302 – Industry and the Environment
Topic 6

Solid Waste Management

- Any non-liquid material that is thrown away or discarded as useless and unwanted is considered to be **solid waste**.
- Improper disposal of solid waste can cause serious environmental or ecological damage.
  - **Air pollution** can result from inadequate solid waste incineration
  - **soil contamination**
  - Surface **water** and groundwater **pollution**, can be caused by the disposal of solid waste in improperly built landfills.
- There is connection between improper solid waste disposal and **public health**.
- Solid waste can host rodents and insects, which may act as vectors of infectious diseases such as typhoid, plague, and dysentery.

- Waste is a **human-derived** word
- Materials are considered **a waste** when owners and society **believe** they **no longer have value**.

Sources of Solid Wastes:

- **Municipal solid waste (MSW)**
  - The term municipal solid waste is generally used to describe most of the nonhazardous solid waste from a city, town, or village that requires routine or **a periodic collection** and transport to a processing or disposal site.
- **Industrial solid waste**
  - Wastes arising form industrial activities
  - Some of industrial waste is classified as hazardous waste
- **Agricultural**
- **Mining**

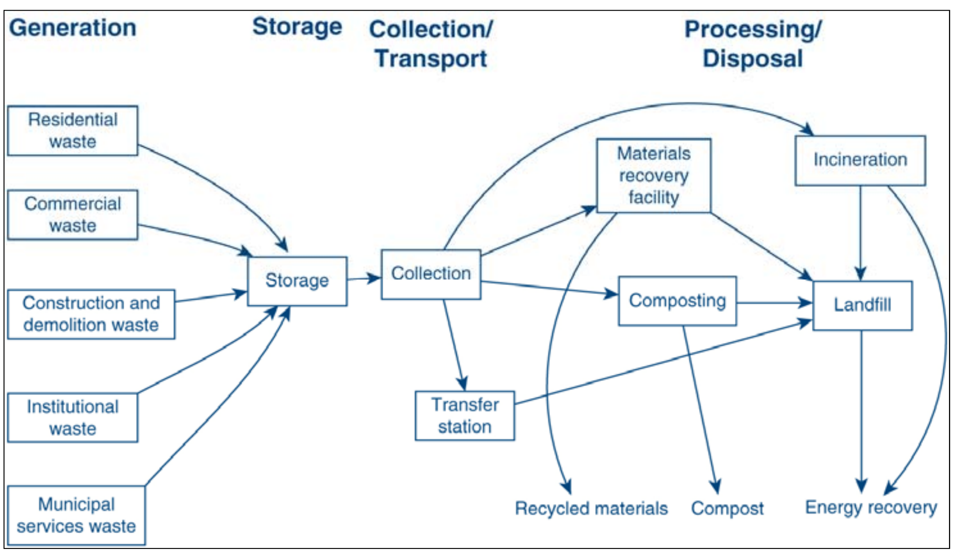
Sources of Solid Waste and Typical percentage that makes up Municipal Solids Waste

Source	Examples	Comments	Typical Pe of MSW
Residential	Detached homes, apartments	Food wastes, yard/garden wastes, paper, plastic, glass, metal, household hazardous wastes.	30–50%
Commercial	Stores, restaurants, office buildings, motels, auto repair shops, small businesses	Same as above, but more variable from source to source. Small quantities of specific hazardous wastes.	30–50%
Institutional	Schools, hospitals, prisons, military bases, nursing homes	Same as above; variable composition between sources.	2–5%
Construction and demolition	Building construction or demolition sites, road construction sites	Concrete, metal, wood, asphalt, wallboard, and dirt predominate. Some hazardous wastes possible.	5–20%

Sources of Solid Waste and Typical percentage that makes up Municipal Solids Waste

Source	Examples	Comments	Typical Per of MSW
Municipal services	Cleaning of streets, parks, and beaches; water and wastewater treatment grit and biosolids; leaf collection; disposal of abandoned cars and dead animals	Waste sources vary among municipalities.	1–10%
Industrial	Light and heavy manufacturing, large food-processing plants, power plants, chemical plants	Can produce large quantities of relatively homogeneous wastes. Can include ashes, sands, paper mill sludge, fruit pits, tank sludge.	Not MSW
Agricultural	Cropping farms, dairies, feedlots, orchards	Spoiled food wastes, manures, unused plant matter (e.g., straw), hazardous chemicals.	Not MSW
Mining	Coal mining, uranium mining, metal mining, oil/gas exploration	Can produce vast amounts of solid waste needing specialized management.	Not MSW

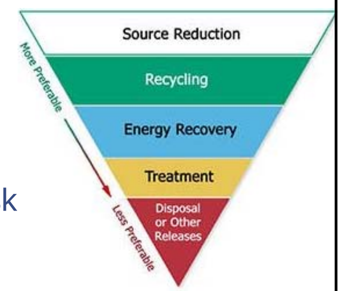
- **Solid waste management** requires an understanding of waste generation, storage, collection, transport, processing, and disposal.



Overview of the Solid Waste Management System

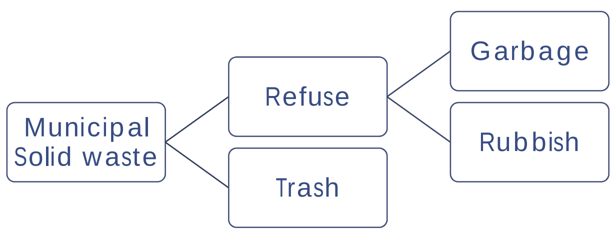
Proper management of solid wastes has five main objectives:

1. Follow the **pollution prevention hierarchy**, which prefers **source reduction and recycling** over treatment and disposal.
2. Protect public health.
3. Protect the environment (including biodiversity) and view the waste material as a resource.
4. Address social concerns (equity, environmental justice, aesthetics, risk public preferences, recycling & renewable energy).
5. Minimize economic, social, and environmental costs.



pollution prevention hierarchy

Types of Municipal Solid Waste



- **Garbage** contains **putrescible** or highly decomposable food waste, such as vegetable and meat scraps.
- **Rubbish** contains mostly dry, **non-putrescible material**, such as glass, rubber, metal cans, and lowly decomposable or combustible material, such as paper, textiles, or wood objects.
- **Trash** includes bulky waste materials that generally require special handling and is therefore not collected on a routine basis. An old couch, mattress, television, or refrigerator and even a large uprooted tree stump are examples of trash items.

Quantities and MSW

- Information regarding the **weight**, **volume**, and the **composition** of the MSW is important for the proper planning, design, and operating of collection and disposal facilities.
- In Saudi Arabia, about 15 million tons of MSW/year.
- (1.5-1.8) kg are generated per person every day.

The actual number will vary for each community depending on:

1. The time of year
2. The location
3. Commercial and industrial activities

Composition of Solid Wates (USA)

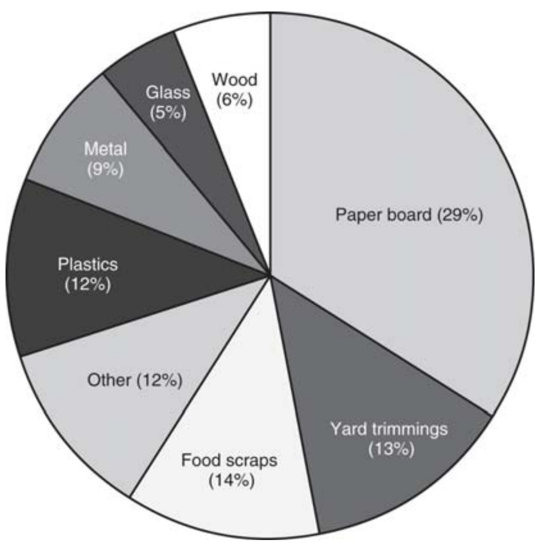


FIGURE 11-3 MSW components in the United States (percent by weight), before recycling (2010).

In Saudi Arabia:*

- Recycling rate ranges from 10-15% (low rate).
- Recycling activities are mostly manual and labor intensive.
- **Composting** is also gaining increased interest in Saudi Arabia due to the high organic content of MSW (around 40%).

*http://www.ecomena.org/tag/msw-in-saudi-arabia/

MSW Management Strategy (3 main components)

1- Source reduction (waste prevention) includes:

- reuse of products on-site
- packaging to reduce their quantity
- on-site composting of garden trimmings

2- Recycling

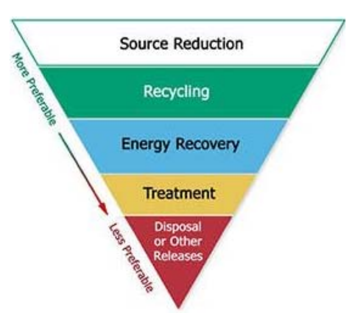
- off-site recovery and processing for reuse
- off-site composting

3- Energy recovery

4- Treatment

5- Disposal

- incineration
- landfills



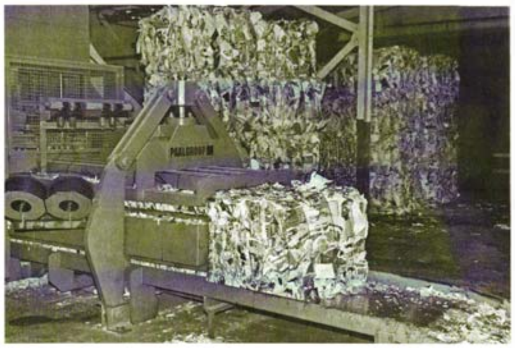
Solid Waste Collection

- It includes:
  - **Temporary storage** and containerization
  - **Transfer** to a collection vehicles
  - **Transport** to a processing facility or disposal site
- About **2/3 of the total cost for MSW management is needed for waste collection** → it is labor intensive
- If source separation is applied, the recyclable material (e.g. Plastic, Paper, ... etc.) can be collected separately from non-recyclable garbage and rubbish.
- **Transfer stations** solid wastes from individual collection trucks are consolidated into larger truck, economical way to transport the solid waste over the long-haul distance to the processing and disposal site.

Solid Waste Processing

- The purpose of MSW processing is to:
  - **Reduce the total volume and weight** that needs final disposal,
  - **Improve its handling** characteristics, and
  - **Recover natural resources** and energy for reuse.
- The commonly used processes for MSW includes:
  - Sorting and separating
  - Shredding
  - Pulverizing
  - Baling
  - Composting
  - Incineration

- **Shredding** (cutting and tearing) or **pulverizing** (crushing and grinding) can achieve size reduction of solid waste.
- **Baling** involves compaction of the waste into the form of rectangular blocks, which are wrapped with steel wire to retain their shape during handling



High pressure compaction units can be used for making rectangular bales or block of solids waste

- **Composting** is a biological process that allows the organic portion of MSW to decompose under controlled conditions, transforming the waste into a potentially beneficial material called **compost** (humus)

- **Recycling** involves separating out and reusing the components of the MSW stream that have some economic value, including **metals, paper, glass,** and **plastic** (Aluminum has the highest recycling value).
- Separation can be done at the source or at a centralized waste processing plant.

Labels on paper products with Mobius arrows

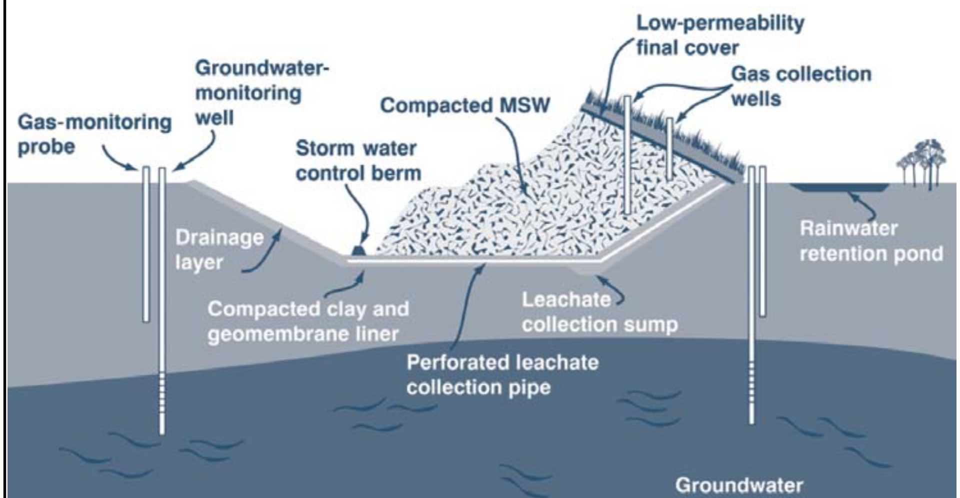
Type of Plastics Found in Commercial Products with Resin Code Used to Aid Recovery

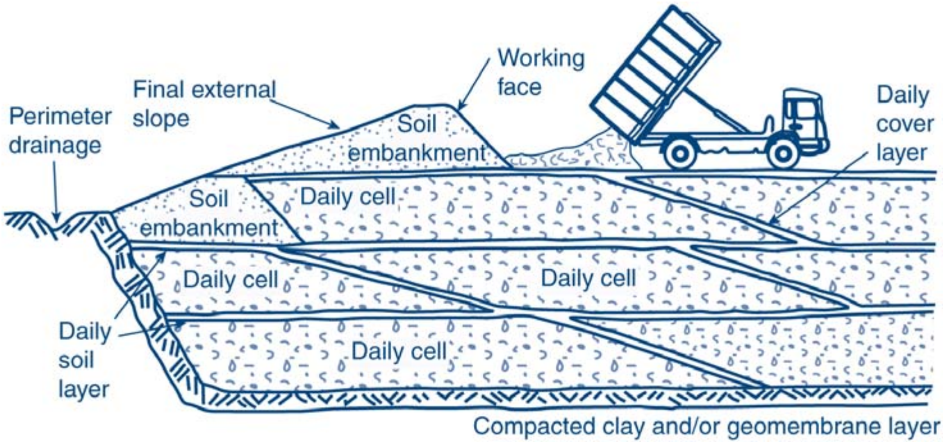
Resin Code	Material	Sample Applications
1	Polyethylene terephthalate (PET)	Plastic bottles for soft drinks; food jars
2	High-density polyethylene (HDPE)	Bottles for milk; bags for groceries
3	Polyvinyl chloride	Blister packs; bags for bedding, pipe
4	Low-density polyethylene	Bags for dry cleaning and frozen foods
5	Polypropylene	Containers for takeout meals
6	Polystyrene	Cups and plates; furniture and electronics packaging

Sanitary Landfill

- Ultimately, a portion of the MSW stream is disposed of in a sanitary landfill, which is a carefully planned and engineered facility.
- The key characteristics that distinguish landfills from old-fashioned "dumps" are as follows:
  - Waste is placed in a suitably **selected and prepared site** in a carefully prescribed manner.
  - Waste material is **spread out in layers** and **compacted** with appropriate heavy machinery.
  - Waste is **covered** each day with a layer of compacted soil
- In addition, all landfills are deigned to prevent groundwater pollution by the **leachate** (polluted liquid) seeping out from the bottom of the landfill.

Landfill is generally the most economical alternative for MSW disposal, although It has become increasingly difficult to find suitable sites for new landfills.





The basic building block of a sanitary landfill is a compacted cell of solid waste, which is separated from other cells by a layer of compacted soil

Riyadh landfill

Sanitary Landfill site selection

- The most important factors in landfill **site selection** are:
  1. volume capacity
  2. accessibility
  3. hydrogeological condition
- Accessibility refers to the ease with which collection or transport vehicles can reach the disposal area without causing a public nuisance or hazard.
- Local geology and hydrology (hydrogeology) have a direct influence on the possibility of water pollution
- Modern landfills are also called **containment landfills** because they are constructed with **bottom liners**. The liners confine the **leachate** and prevent it from mixing with groundwater.

Example-1: (Service years for landfill)

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

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 years (365 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

Solution:

Capacity of the landfill =

500 m x 1000 m x 10 m x 400 kg/m^3 = 2 x 10^9 kg

Daily MSW production rate of the city =

600,000 capita x 2 kg/capita · day = 1.2 x 10^6 kg/day

Number of years that the landfill will serve =

$$\frac{2\text{ X }10^9\text{ kg}}{1.2\text{ X }10^6\text{ kg/day}} = 1666.7\text{ days} = 1666.7\text{ days}\cdot\frac{1\text{ year}}{365\text{ days}} = 4.57\text{ years}$$

Hazardous Wastes

- MSW is not generally considered to be hazardous, but certain types of commercial or industrial wastes are characterized as hazardous waste that can cause immediate and direct harm to people or the environment if disposed of improperly.
- **Hazardous Waste** is defines as a solid waste that may cause or significantly contribute to an increase in mortality or an increase in serious irreversible or incapacitating reversible illness; or pose a substantial present or potential hazard to human health or the environment when it is improperly treated, stored, transported, or dispose of.
- This **hazardous waste** typically requires **transport, processing, and disposal** methods that are different from those required for nonhazardous MSW.

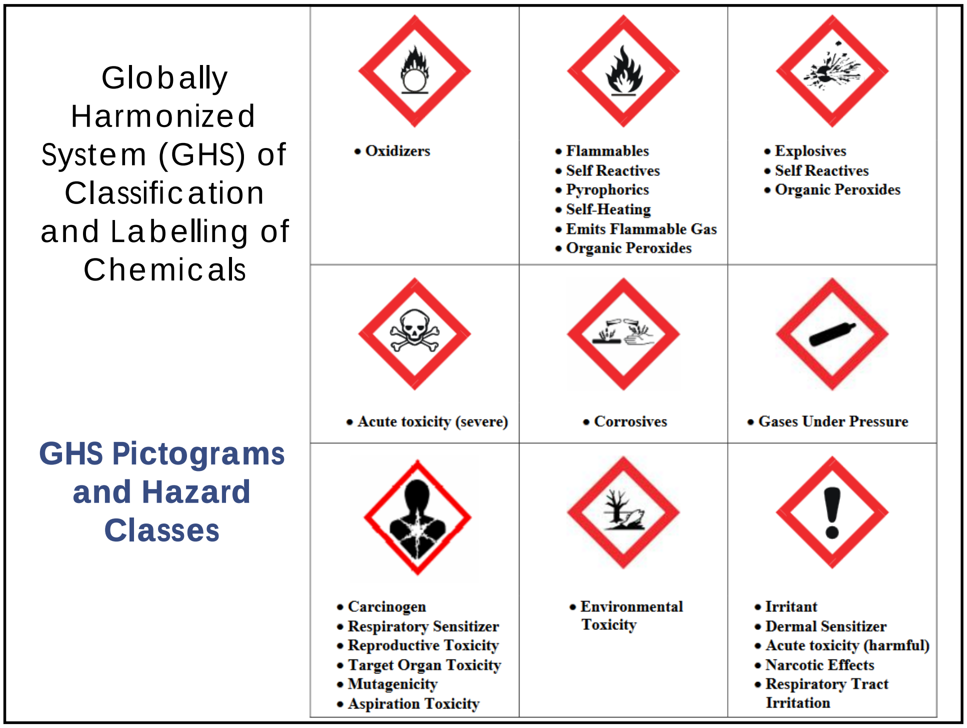
Methods to Classify a Solid Waste as Hazardous

Characteristic of Waste	Question Related to Characteristic
Ignitable	Can the waste create a fire (e.g., waste solvents)?
Corrosive	Is the waste very acidic or basic and so able to corrode storage containers (e.g., battery acids)?
Reactive	Can the waste participate in rapid chemical reactions leading to explosions, toxic fumes, or excessive heat (e.g., lithium that can react with water explosively, explosives, cyanide sludge, strong oxidizing agents)?
Toxic	Can the waste cause internal damage to a person or organism (e.g., poisons causing death or blindness, carcinogens)?
Radioactive	Can the waste release subatomic particles that can cause toxic effects (e.g., some medical and laboratory wastes, wastes associated with nuclear energy production)?
Infectious	Can the waste lead to the transmission of disease (e.g., used syringes, hospital medical wastes)?

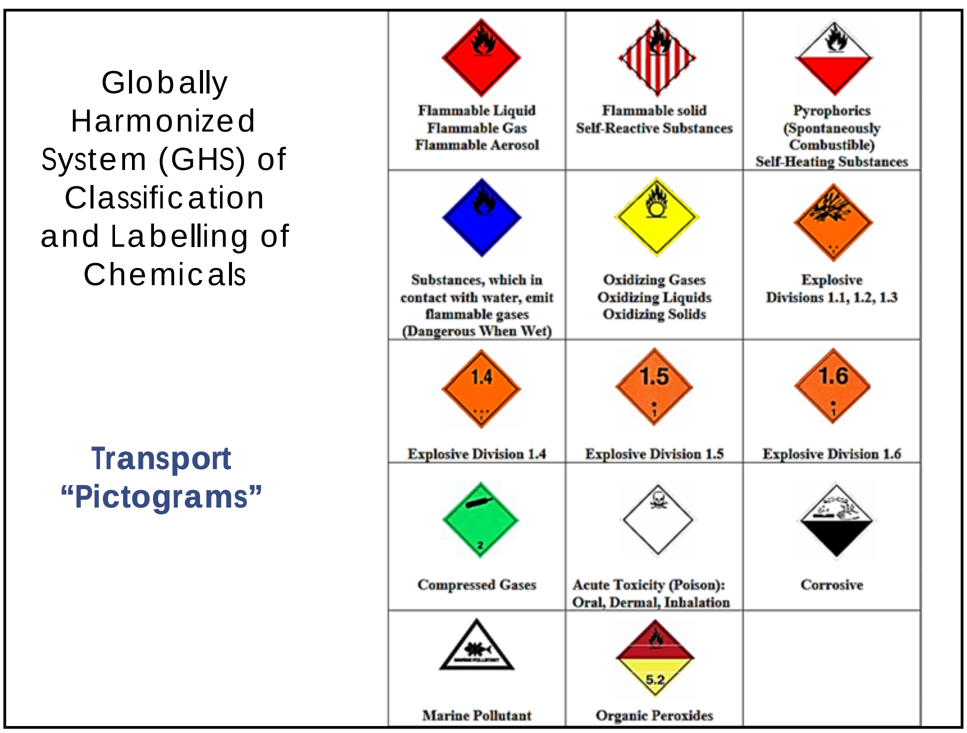
Common Hazardous Products Found in Households

Product	Concern
Household Cleaning Products	
Oven cleaners	Corrosive
Drain cleaners	Corrosive
Pool acids, chlorine	Corrosive
Chlorine bleach	Corrosive
Automotive products	
Motor oil	Ignitable
Antifreeze	Toxic
Car batteries	Corrosive
Transmission and brake fluid	Ignitable
Lawn and garden products	
Herbicides, insecticides	Toxic
Wood preservatives	Toxic
Indoor pesticides	
Flea repellents and shampoos	Toxic
Moth repellents	Toxic
Mouse and rat poisons	Toxic
Home maintenance/hobby supplies	
Oil or enamel-based paints	Flammable
Paint solvents and thinners	Flammable

It is important that these materials be disposed of safely and kept out of the municipal waste stream.



Globally Harmonized System (GHS) of Classification and Labelling of Chemicals
GHS Pictograms and Hazard Classes
• Oxidizers
• Flammables
• Self Reactives
• Pyrophorics
• Self-Heating
• Emits Flammable Gas
• Organic Peroxides
• Explosives
• Self Reactives
• Organic Peroxides
• Acute toxicity (severe)
• Corrosives
• Gases Under Pressure
• Carcinogen
• Respiratory Sensitizer
• Reproductive Toxicity
• Target Organ Toxicity
• Mutagenicity
• Aspiration Toxicity
• Environmental Toxicity
• Irritant
• Dermal Sensitizer
• Acute toxicity (harmful)
• Narcotic Effects
• Respiratory Tract Irritation



Globally Harmonized System (GHS) of Classification and Labelling of Chemicals
Transport "Pictograms"
Flammable Liquid
Flammable Gas
Flammable Aerosol
Flammable solid
Self-Reactive Substances
Pyrophorics (Spontaneously Combustible)
Self-Heating Substances
Substances, which in contact with water, emit flammable gases (Dangerous When Wet)
Oxidizing Gases
Oxidizing Liquids
Oxidizing Solids
Explosive
Divisions 1.1, 1.2, 1.3
1.4
Explosive Division 1.4
1.5
Explosive Division 1.5
1.6
Explosive Division 1.6
Compressed Gases
Acute Toxicity (Poison): Oral, Dermal, Inhalation
Corrosive
Marine Pollutant
5.2
Organic Peroxides