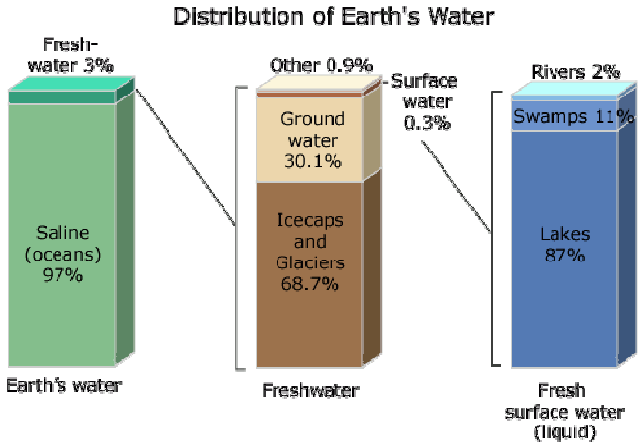
Water Quality

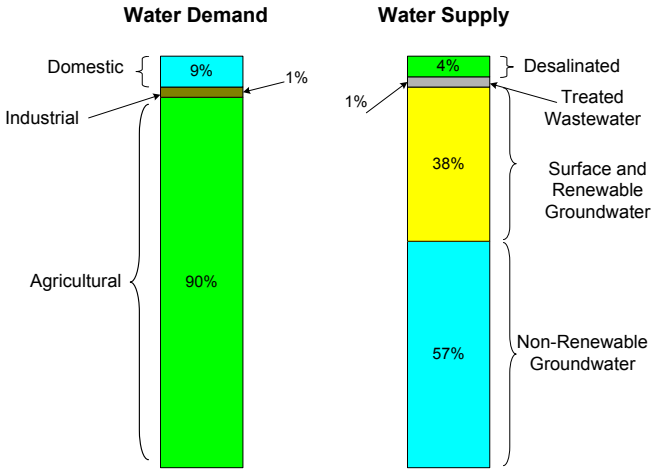
CE 370 – Lecture 1

Global Distribution of Earth's Water



Water Demand and Supply in Saudi Arabia

Total Water Consumption = 22 billion m^3/Year

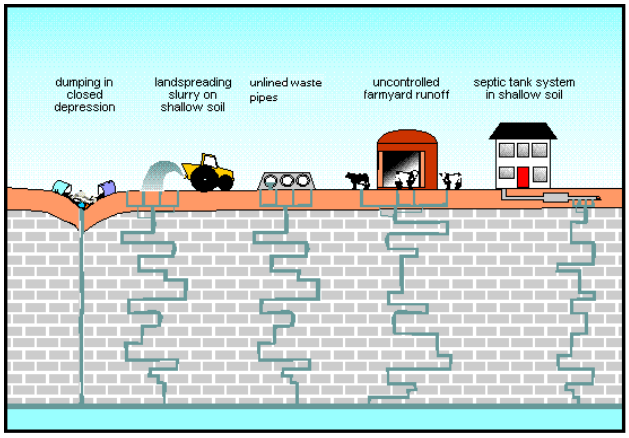


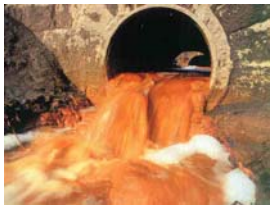
The Quality of this Fresh Water is Vitally Important, Why?

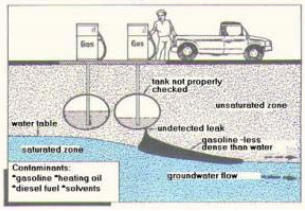
- We depend on surface and groundwater sources for our drinking water.
- We also need water to generate energy, to grow our crops, to harvest fish, to run machinery, to carry wastes, to enhance the landscape.
- We use water for washing and cleaning, industrial abstraction, recreation, cooking, gardening, etc..
- Water is also vital as a habitat for both freshwater and marine plants and animals.

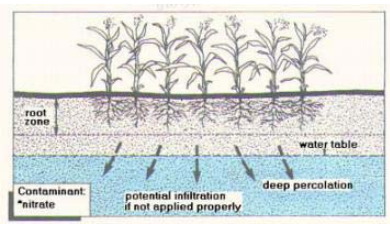
What Causes Water Pollution?

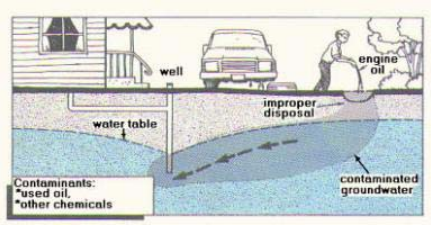
- Human Activities











Need for testing water quality

- For drinking water:
  - To assess safety and palatability of water for consumption
- For raw water sources:
  - To select treatment systems; to establish pollution control monitoring systems
- For wastewaters:
  - To select type and degree of treatment; to control treatment plant operation
- For receiving waters:
  - To evaluate their ability to accept pollution loads; to monitor self-purification

Types of Examination:

- Physical examination:
  - to determine aesthetic quality
- Chemical examination:
  - To test for chemicals which affect the water quality and/or which are indicative of pollution
- Bacteriological examination:
  - To test for the presence of bacterial indicators of pollution and hence safety for consumption
- Biological examination:
  - To determine the causes of objectionable odors, clogging of filters, etc.

Some salient water quality parameters:

- Temperature
- Turbidity
- Odors and Tastes
- Color
- pH
- Alkalinity and Acidity
- Chlorides
- Nitrogen compounds (organic N, ammonia N, nitrite N, nitrate N)
- Hardness
- Fluorides
- Iron and Manganese
- Sulfates
- Residual Chlorine
- Total Dissolved Solids
- Dissolved Oxygen
- Biochemical Oxygen Demand
- Chemical Oxygen Demand
- Coliforms

Temperature:

- Surface waters fluctuate in temperature with season; in groundwaters there is only a small variation.
- Significance:
  - warm waters taste flat
  - Influences rates of chemical and biological activities
  - Influences the saturation values of dissolved gases
  - Heat pollution
  - Fish kill when more than 30 - 35oC.

Turbidity:

- Turbidity represents lack of clearness in water (measure of interference presented by suspended matter to passage of light).
- Turbidity is due to:
  - clay, silt, finely divided organic matter, microorganisms
- Water in:
  - lakes and ponds: less turbid
  - rivers: more turbid
  - wells: low turbidity
- Significance:
  - Aesthetic consideration
  - Influences disinfection
  - affects filterability

Odors and tastes:

- Odors are caused by volatile substances associated with:
  - oragnic matter (decaying)
  - living organisms (algae)
  - gases (hydrogen sulfide, chlorine)
- Tastes are caused by:
  - chlorides and sulfates of calcium, magnesium and sodium
  - organisms (algae)
  - industrial wastes

pH:

- pH: Common logarithm of the reciprocal of hydrogen ion concentration
- pH is an intensity factor.
  - pH = 7: Neutral
  - pH < 7: Acidic
  - pH > 7: Alkaline
- pH of most raw water sources: 6.5 - 8.5
- Significance:
  - Influences chemical reactions (in coagulation, softening, disinfection, etc.)
  - Corrosion problems (low pH)
  - Many industrial waters require rigid pH control
  - Optimum pH required for fish and other aquatic life
  - Sudden pH changes affect aquatic life

Alkalinity:

- Capability to neutralize acids; Expressed in mg/L as $CaCO_3$.
- Most waters are alkaline because alkaline salts are common in groundwater
- Alkalinity in water is due to:
  - carbonates
  - Bicarbonates
  - Hydroxides
- Alkalinity is mostly due to bicarbonates of Ca, Mg and Na.
- Significance:
  - Important in water treatment (especially coagulation)
  - In industrial waters: deposits, corrosion of steam lines
  - Many industrial waters require rigid pH control

Chlorides

- Chlorides are present in all water sources.
- Chlorides get into water from:
  - mineral deposits
  - domestic wastewater discharges
  - industrial wastewaters
  - Irrigation drainage
  - Human excreta (urine) contains chloride, about 6g/capita.d
- Significance:
  - Undesirable taste
  - Contributes to hardness
  - In industrial waters: deposits, boiler corrosion
  - Natural waters have a uniform chloride content. An increase above the normal chloride level is an index of pollution by domestic wastewaters.

Nitrogen Compounds

- Forms of nitrogen:
  - Organic nitrogen
  - Ammonia nitrogen
  - Nitrite nitrogen
  - Nitrate nitrogen
- The presence of various nitrogen forms is an indication of the pollutional history of the carrying water.

Nitrogen Compounds

Continue

- Organic nitrogen:
  - Animal tissue is richer in nitrogen than plant tissues. So, higher concentration indicates pollution by wastes of animal origin.
  - Characteristic of recent pollution
- Ammonia nitrogen:
  - Initial product of decomposition, and hence indication of recent pollution
  - Always found in sewage polluted waters
  - Toxic to fish

Nitrogen Compounds

Continue

- Nitrite nitrogen:
  - Oxidation product of ammonia nitrogen (Intermediate product)
  - Nitrites are easily and rapidly converted to nitrates, hence indication of active biological processes
- Nitrate nitrogen:
  - End product of decomposition of organic matter

Hardness

- Common in groundwater.
- Water is hard when it does not readily form lather with soap.
- Hardness in water is due to:
  - calcium (Ca) and magnesium (Mg)
  - Carbonate hardness: due to carbonates and bicarbonates of Ca and Mg
  - Non-carbonate hardness: due to chlorides and sulpfates of Ca and Mg
- Significance:
  - scale build-up in boilers and hot water systems
  - excessive soap usage
  - fuel wastage
  - poor cleaning of clothes and reduced fabric life
  - health effects: minor: laxative effects.

Iron and Manganese

- Common in groundwater
- Iron
  - from soil, rock and plant matter
  - from pipes; from coagulants
- Significance:
  - stains plumbing fixtures and clothes
  - growth of iron bacteria in pipe lines (red water complaints)
  - corrosion of pipe lines
  - taste and odor problems
- Manganese:
  - though often associated with iron, less common
  - problems similar to iron - black water complaints

Sulfates

- Occurs in water from:
  - solvent action of water on gypsum and other salts
  - decomposition of organic matter
  - industrial wastewaters
  - atmospheric SO_2 (acid rain)
- Significance:
  - laxative effects
  - tastes
  - scales in boilers
  - hardness

Fluorides

- Occurs in water from:
  - fluoride-containing minerals in the ground
  - industries (fertilizers, bricks, ceramics, pharmaceutical products)
- Significance:
  - less than 1 mg/L: dental caries
  - more than 1.5 mg/L: mottling of enamel of teeth
  - 3 to 6 mg/L: skeletal fluorosis
  - more than 10 mg/L: crippling skeletal fluorosis
  - (Influence of temperature?)

Dissolved Oxygen (DO)

- Oxygen-content of water
  - Biological decomposition of organic matter uses up the dissolved oxygen. Hence DO is the most important single criterion indicating the sanitary condition of water.
  - Water deficient in DO is likely to be polluted with organic matter (Groundwater ?)
- Significance:
  - Measure of the impact of oxidizable wastes in water
  - Lack of DO affects fish and aquatic life
  - Measure of progress of self-purification in rivers
  - Influences precipitation of metals like Al and Fe
  - For determining biochemical oxygen demand of wastewaters

Biochemical Oxygen Demand (BOD)

- Definition:
  - BOD is a measure of the DO required for the utilization of organic matter as food by the aerobic microorganisms.
  - BOD is measured by DO determination before and after an incubation period of 5 days at $20^{o}C$
  - BOD is an indirect measure of the amount of readily biodegradable organic matter.
  - It is a measure of the strength of wastewater.
- Significance:
  - Pollutional strength of domestic and industrial wastewaters
  - Evaluation of self-purification capacity of receiving waters
  - Assessing efficiency of wastewater treatment processes

Chemical Oxygen Demand (COD)

- COD is obtained by oxidizing the waste with boiling acid dichromate solution.
- In a COD test, 95% of organic matter is oxidized, and results are available within 3 hours.
- Significance:
  - COD test provides no information on the proportion of waste that can be oxidized by microorganism.
  - It does not distinguish between stable and unstable organic matter.
  - It is very useful for industrial wastewaters

Total Dissolved Solids (TDS)

- TDS represents mainly inorganic substances
- Principal constituents are: bicarbonates, chlorides and sulfates of Ca, Mg, and Na.
- There is generally an increase of hardness with TDS.
- Significance:
  - Taste
  - Laxative effects
  - Indication of hardness
  - Waters with high TDS not desirable for industries

Coliforms

- Testing for pathogens is very difficult
  - A wide variety of pathogens.
  - Tests for pathogens difficult and time consuming
  - The number of pathogens present is small
- Indicator organisms:
  - Organisms normally present in the feces of human are used as indicator organisms. If present in water, they indicate the presence of fecal material and hence the presence of intestinal pathogens.
- Coliforms as indicator organisms:
  - The number of coliforms in feces is very large
  - Rates of removal/decay/death of coliforms are parallel to that of pathogens
  - Tests are simple

Drinking Water Standards

- Defined as water quality parameters established for public water supplies by regulatory authorities to define the limiting concentrations of various constituents.
- Limiting concentrations are those that can be tolerated for the intended use.
- Revised periodically

Standards Classifications

- **Primary Standards**: are health related and enforceable which includes such parameters as:
  - Coliforms, turbidity, toxic inorganic and organic chemicals, and radionuclides.
- **Secondary Standards**: are non-health related used for aesthetic purposes which includes:
  - Color, odor, chloride ion, sulfate ion, dissolved solids, manganese, pH, copper, and zinc.

Levels of Standards

- Organizational
- City
- National
- Regional
- International

Some Important World Standards

- **The World Health Organization (WHO)**
  - Set up some guidelines for drinking-water quality which are the international reference point for standards setting and drinking-water safety.
- **The European Union (EU)**
- **The US Environmental Protection Agency (EPA)**
- **Presidency of Meteorology and Environment (PME)**
  - Set up guidelines for Saudi Arabia.