قسم الهندسة المدنية

المرحلة الرابعة

Al-Mansour University College

Civil Eng. Dept.

4th. Stage

Sanitary Engineering

2022 - 2023

الهندسة الصحية

Lec.1

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Department of Civil Engineering
CE 405 Sanitary and Environmental Engineering

Water Demand

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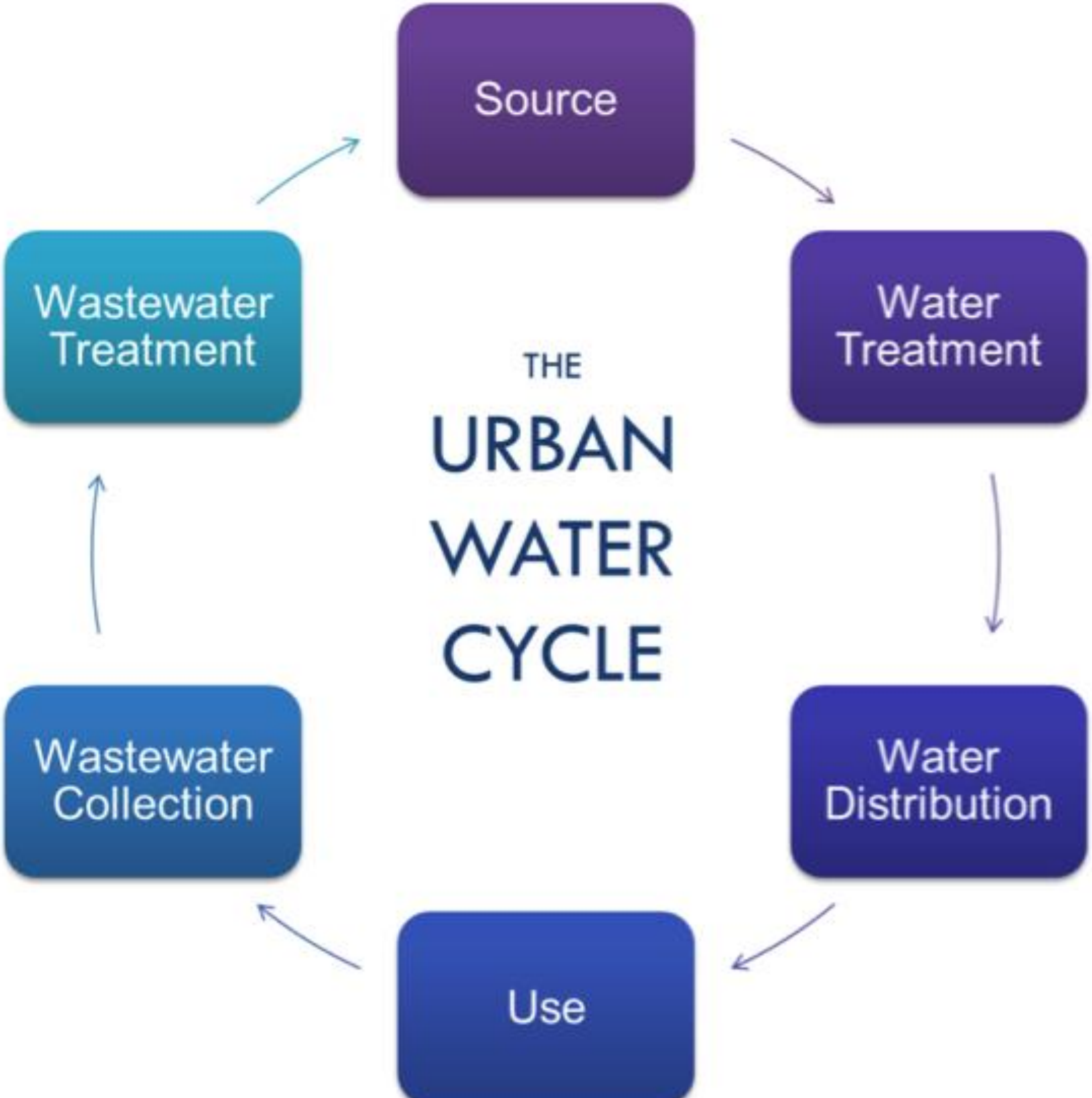
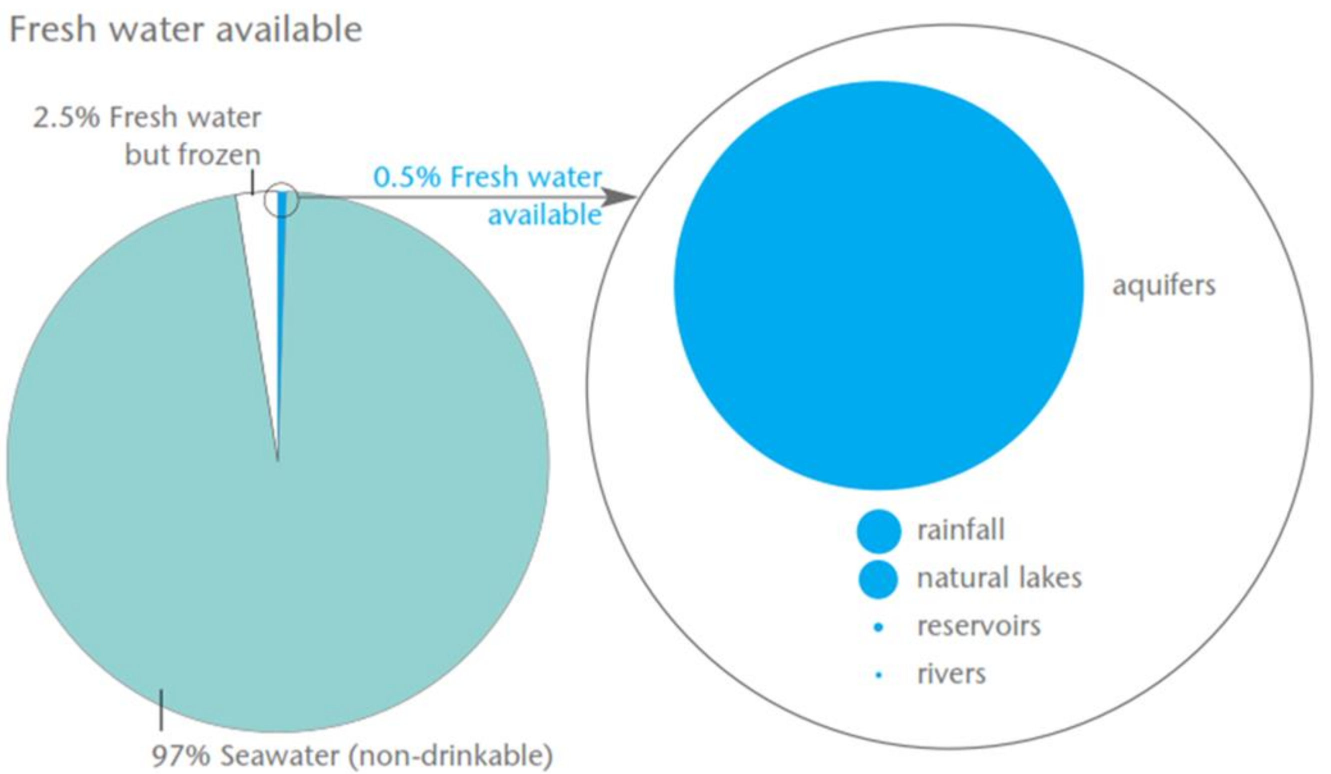
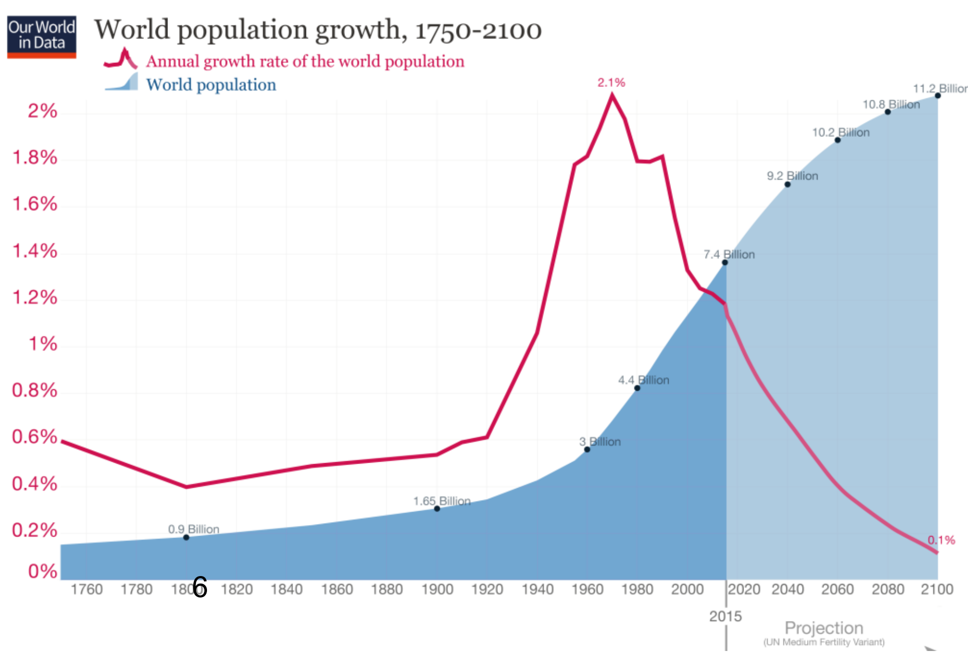

Source
Water Treatment
Water Distribution
Use
Wastewater Collection
Wastewater Treatment
THE
URBAN
WATER
CYCLE

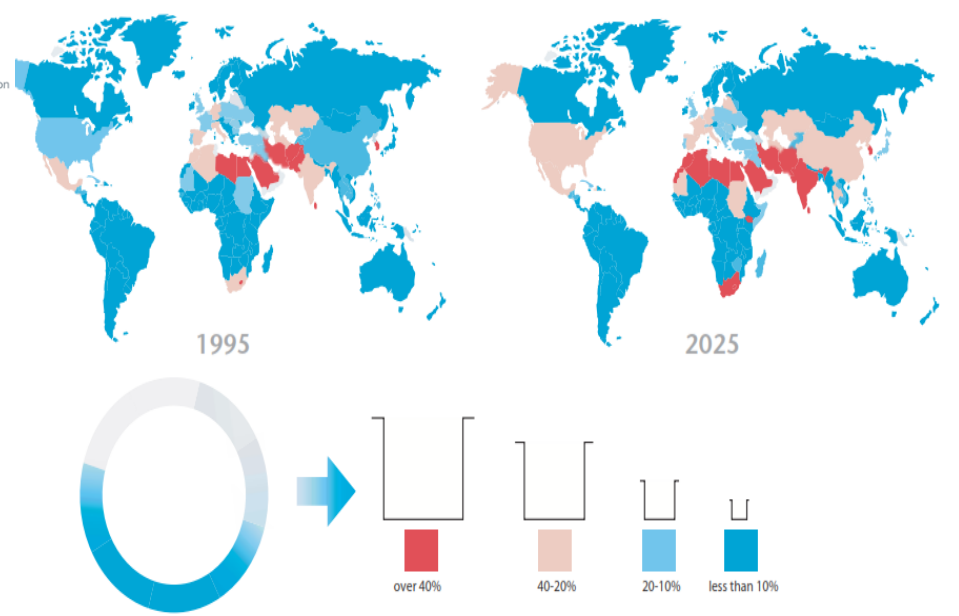
Water global situation

- Less than 3% of the world's water is fresh, the rest is seawater and undrinkable.
- Of this 3% over 2.5% is frozen, locked up in Antarctica, the Arctic and glaciers, and not available to drink.
- Thus humanity must rely on this 0.5% for all of man's and ecosystem's fresh water needs.



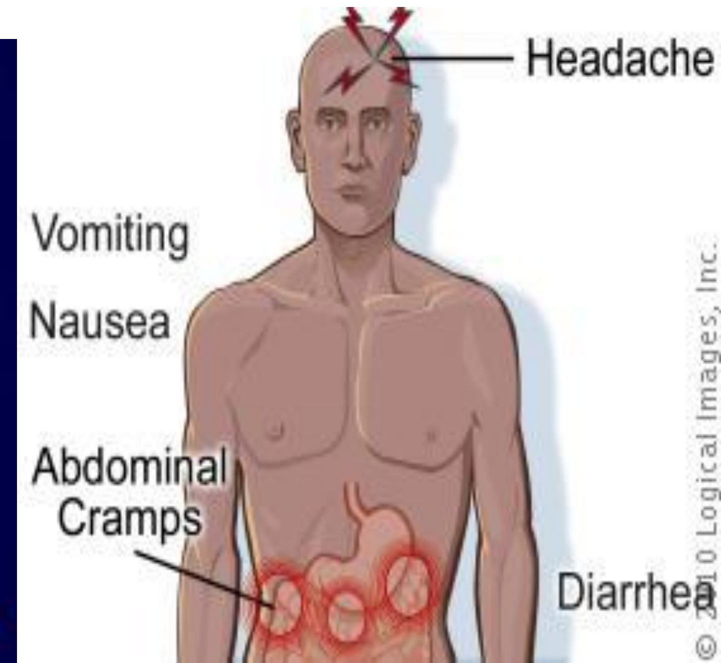
- The current world population is over **7,901,689,215** in 2021. The UN estimates that by 2050 there will be an additional more billion people.
- Most of the growth in developing countries that already suffer water demand.
- Thus water demand will increase unless everyone finds ways to **conserve** and **recycle** the precious resource.





- 3,900 children die each day due to dirty water.
- 1.8 million people die every year from diarrhea diseases (including cholera).





Domestic and non-domestic water demand

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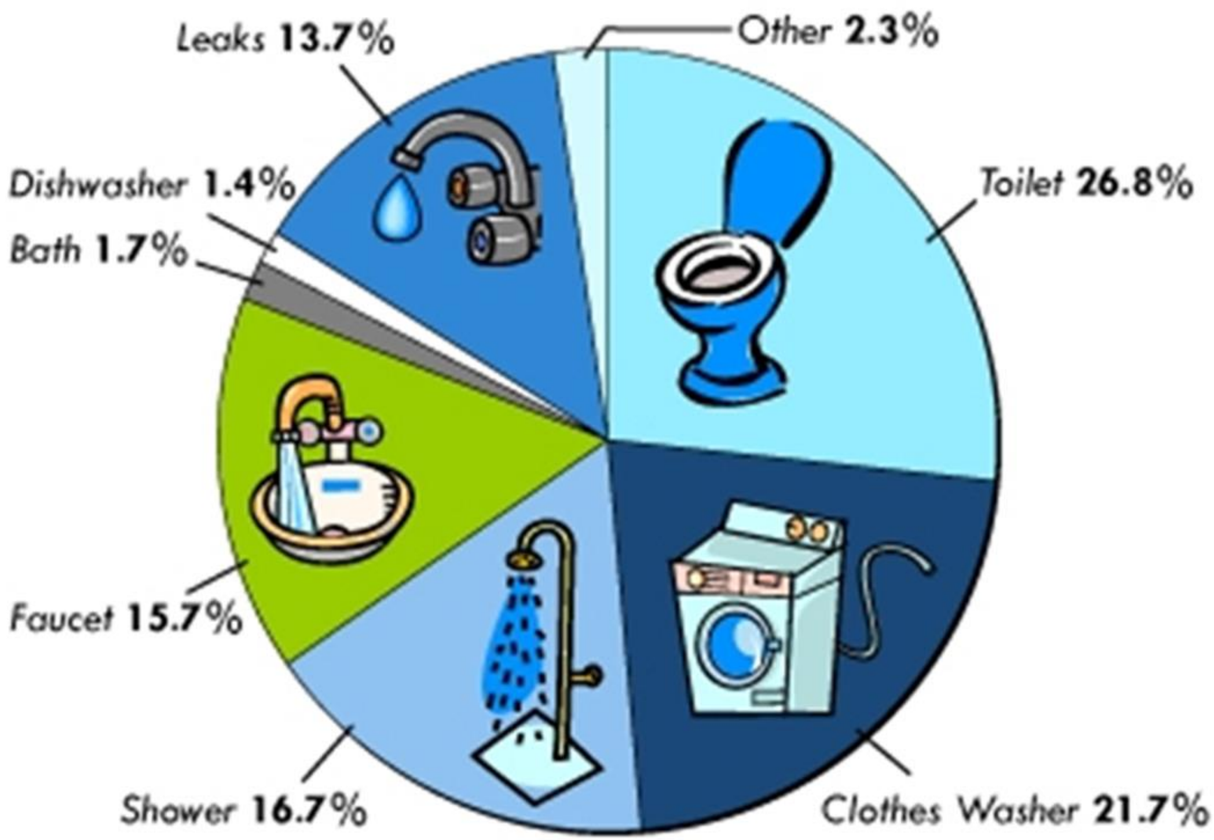
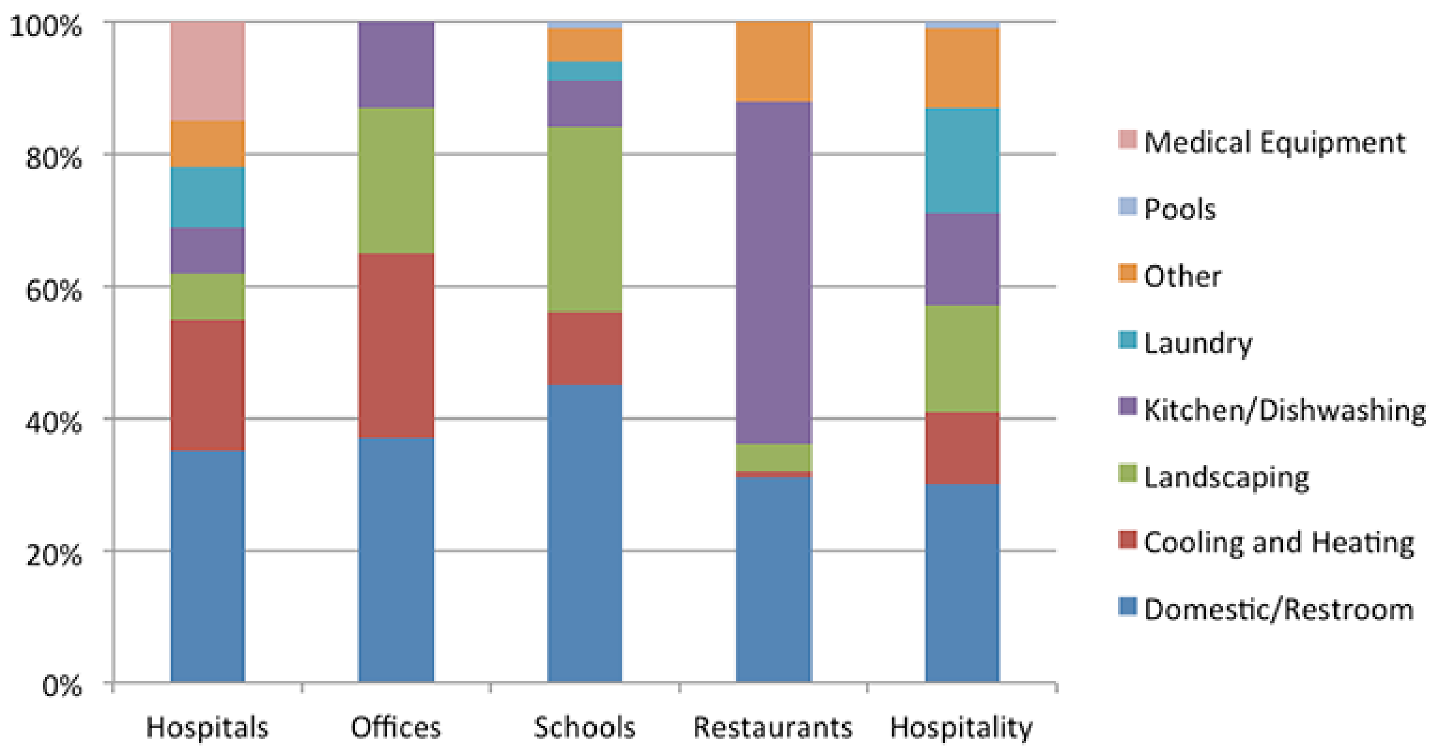
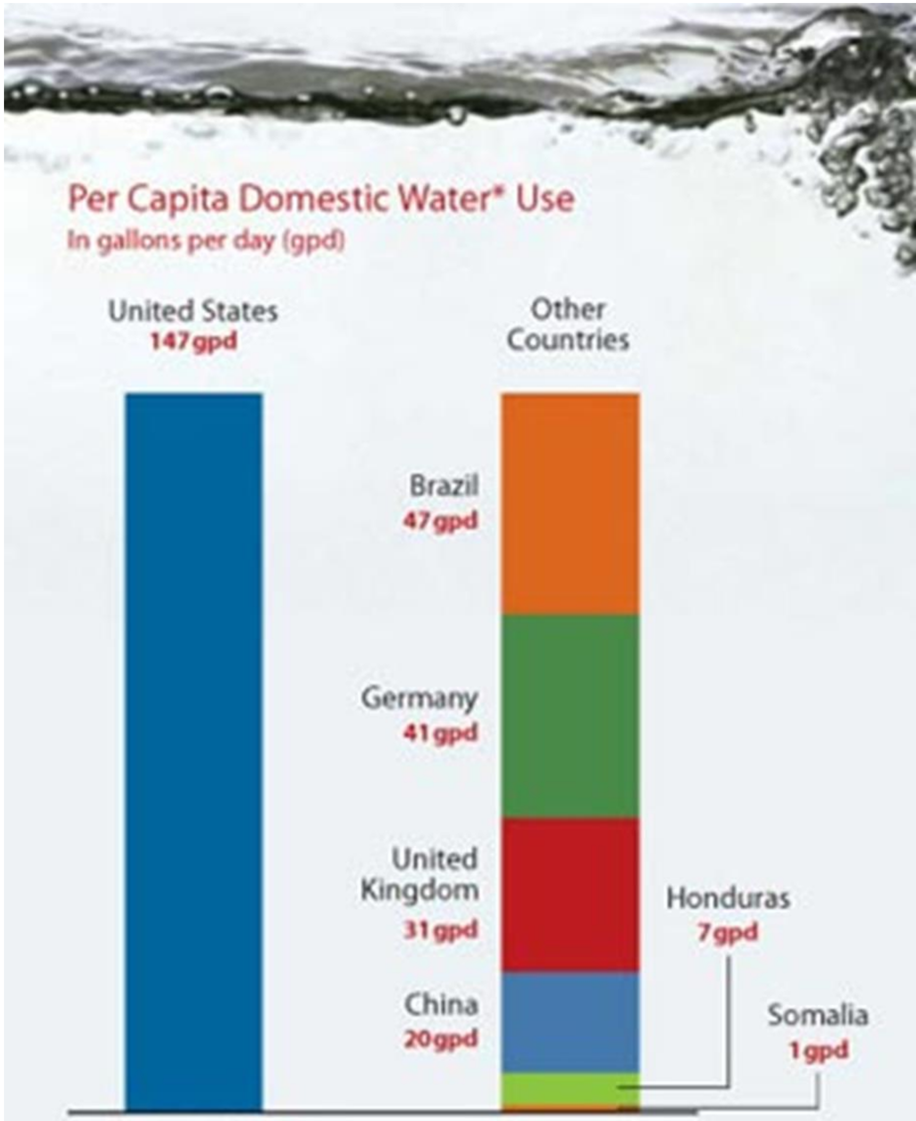


- Non-domestic : covers the use of water mostly for public purposes such hospital, hotels, educational institutions, offices, commercial establishments, railway stations, airports, gardens, swimming pool and theaters.



Factors influencing water demand

- Population
- Season
- Habits and living standard
- Water resources
- Cost of water
- Presence of industry and commerce
- Policy of metering and charging method



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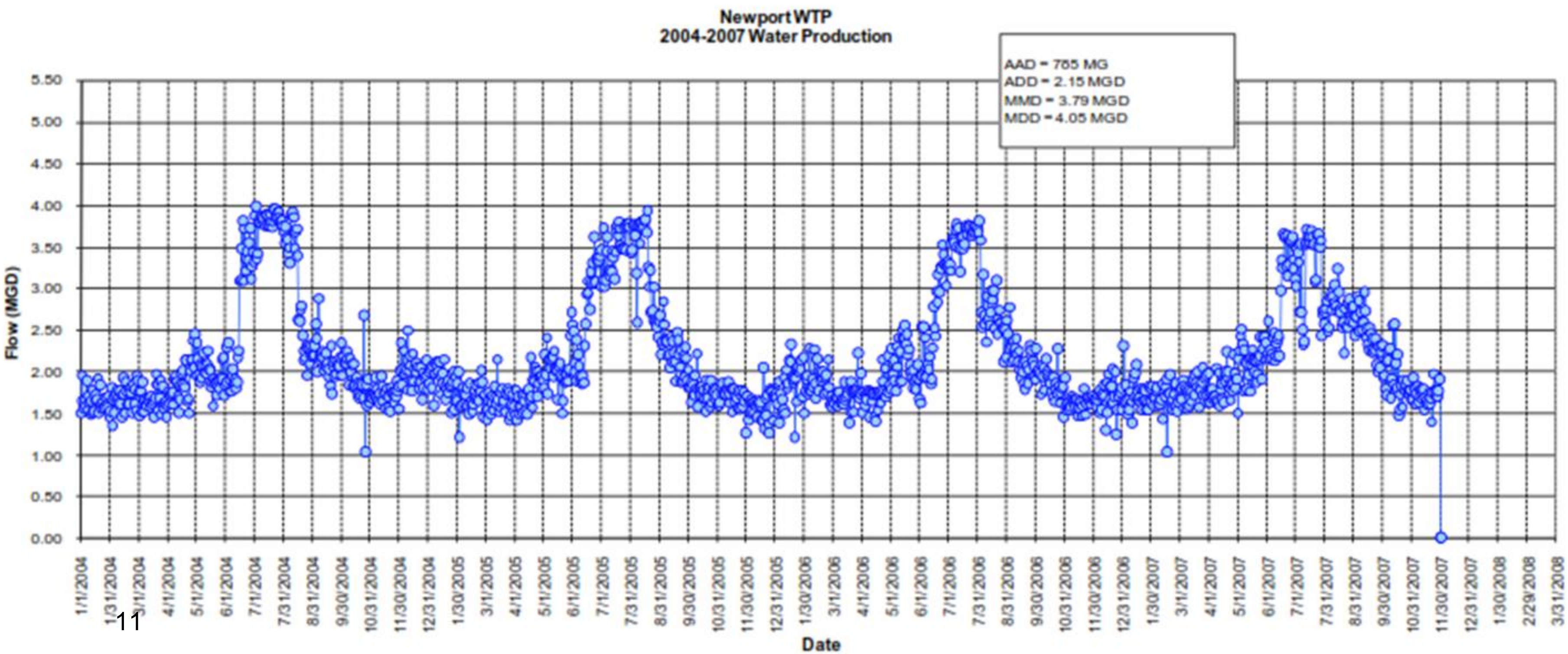
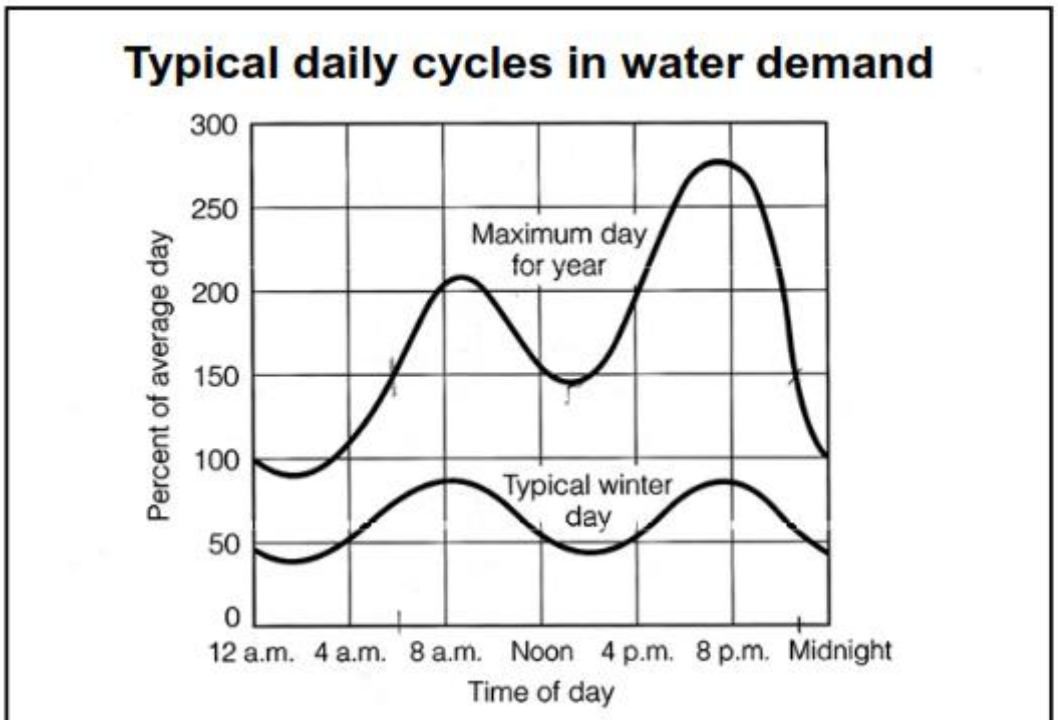
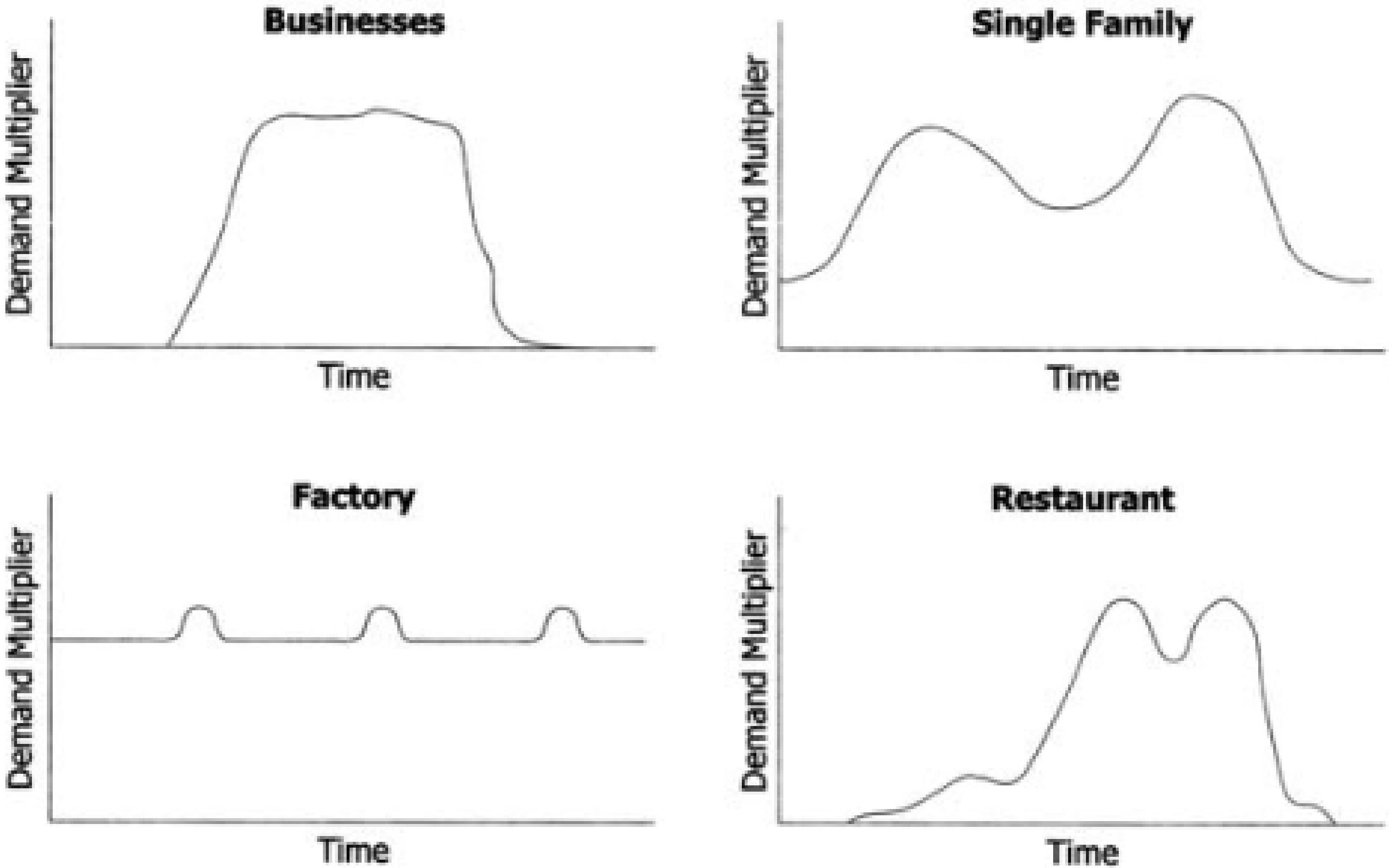
- Diurnal peaks typically occur during the morning and early evening periods, while the lowest usage occurs during nighttime hours.



- Seasonal variations: in Summer daily water consumption rate may reach 120 to 160% of the average daily consumption rate. In Winter, daily water may reach 70%.
- Daily variations: Water consumption varies from one day to another. Daily variation could reach a maximum of 130 to 170% of average daily consumption during the year or may reach a minimum value of 60%.
- Hourly variations: maximum rate may reach to 150 to 225% of average daily rate at the peak.



Diurnal curves for different user categories



- Water demand: the quantity of water that the treatment plant must produce in order to meet all water needs in the community.
- Water demand includes water delivered to the system to meet the needs of consumers, water supply for fire fighting and system flushing, etc.
- Additionally, virtually all systems have a certain amount of leakage that cannot be economically removed and thus total demand typically includes some leakage.

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- It served to come up with a demand per person or per capita which is expressed in gallons per capita per day (gpcd), or demand per EDU (gpd/EDU).
- These unit demands can be multiplied by future population or EDU projections to estimate future water demands for planning purposes.

- **Average Annual Demand** (AAD) : The total volume of water delivered to the system in a full year expressed in gallons/ liters. When demand fluctuates up and down over several years, an average is used.
- **Average Daily Demand** (ADD): The total volume of water delivered to the system over a year divided by 365 days. The average use in a single day expressed in gallons/liters per day.
- **Maximum Month Demand** (MMD): The gallons/ liters per day average during the month with the highest water demand. The highest monthly usage typically occurs during a summer month.
- **Maximum Day Demand** (MDD): The largest volume of water delivered to the system in a single day expressed in gallons/ liters per day. The water supply, treatment plant and transmission lines should be designed to handle the maximum day demand.
- **Peak Hourly Demand** (PHD): The maximum volume of water delivered to the system in a single hour. Distribution systems should be designed to adequately handle the peak hourly demand or maximum day demand plus fire flows, whichever is greater. During peak hourly flows, storage reservoirs supply the demand in excess of the maximum day demand.

GOODRICH FORMULA

$P = 180\, t^{-0.10}$

Where, P = % of annual average draft for the time in days

t = Time in days from 1/ 24 to 365

When t= 1 day (For daily variations)

$P = 180 \times 1^{-0.10}$

P = 180%

Maximum Daily Demand (MDD) = 1.8 x ADD

When t = 7 days (For weekly variations)

$P = 180 \times 7^{-0.10}$

P = 148%

When t = 30 days (For monthly variations)

$P = 180 \times 30^{-0.10}$

P = 128%

Flow demand and design consideration

- Average Daily Demand = Average Annual Demand/ 365
- Maximum Daily Demand = Average Daily Demand x 1.8
- Peak Hourly Demand (PHD) = Maximum Daily Demand x 1.5
- Maximum Hourly Demand = Average Daily Demand X 2.7

- Water supply facilities will serve the maximum daily demand and water tanks will serve peak hour demands
- Design flow for a distribution network should be based on the peak hourly demand or the peak daily demand + fire flow requirements.

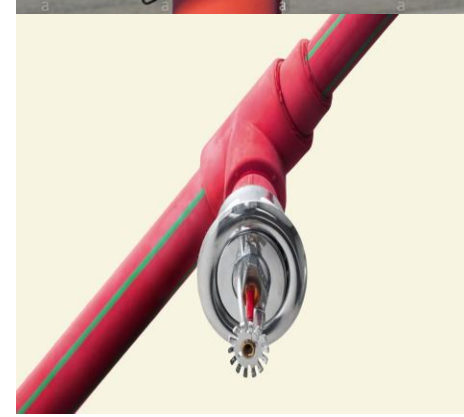
Fire demand

Fire fighting systems:

- **With water**: Small demand annually but high demand during short period.

1. Hydrants: an outdoor system
2. Hose reel: an indoor system
3. Sprinkler: an indoor system

- **Without water**



Fire protection requirements

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$$Q = 1020\sqrt{p}(1 - 0.01\sqrt{p})$$: gal/min (gpm)

$$Q = 4080\sqrt{p}(1 - 0.01\sqrt{p})$$: l/min

Where:

P : population in thousands

Limitation :

1. One fire per day
2. Fire duration 4 -10 hr
3. Population ≤ 200,000 capita

- Insurance Service Office Formula (ISO).

F= 18 * C.$\sqrt{A}$: gpm; area (ft^2)

F= 223.18 * C.$\sqrt{A}$: l/min; area (m^2)

F= 3.724 * C.$\sqrt{A}$: l/sec; area (m^2)

Where:

A: area in ft^2 ; (1m^2 = 10.76 ft^2)

C: coefficient depend on the construction material,

(C) for wood =1.5, fire resistance= 0.6, normal = 1

Limitation:

1. One fire per day
2. Fire duration 4 -10 hr
3. F = 500 – 8000 gal/min (gpm)

Example : A city with population of 22,000 capita has Average Daily Demand (ADD) of 200 lpcd, there is a building of ordinary construction material with each floor area of 1000 m^2 and height of 6 stories, use losses as 20%. Determine:

1. Max daily demand
2. The fire flow demand (use the highest value)
3. Max flow rate during the day with 4 hours fire duration.

Note: 1 meter = 3.28 ft, 1 gallon = 3.785 L

Solution:

1. MDD = ADD * 1.8 = 200 * 1.8 = 360 Lpcd
2. Fire flow demand = 223.18 *C* $\sqrt{A}$ = 223.18* 1* $\sqrt{(1000*6)}$ = 17,287 L/min

Fire flow demand = 4080 x $\sqrt{p}$ (1- 0.01 $\sqrt{p}$) = 4080* $\sqrt{22}$ (1 – 0.01 $\sqrt{22}$)= 18,239 L/min
Use Fire flow demand as 18,239 L/min
For 4 hours duration = 18,239* (60 * 24)*4/24 = 4,377,431 L/day

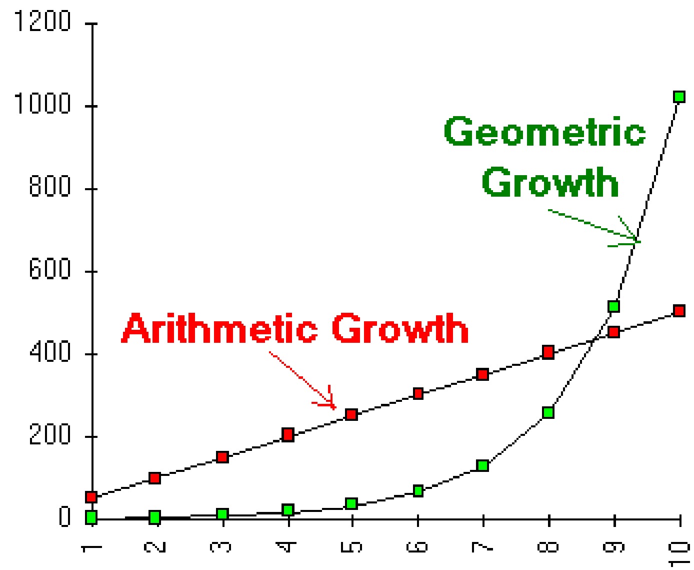
3. Max flow rate during the day = (MDD* pop + Fire flow rate) X (1+ % losses)
= (360 * 22,000 + 4,377,431) X(1+ 0.2)
= (7,920,000 + 4,377,360) *1.2
= 14,756,917 L/day

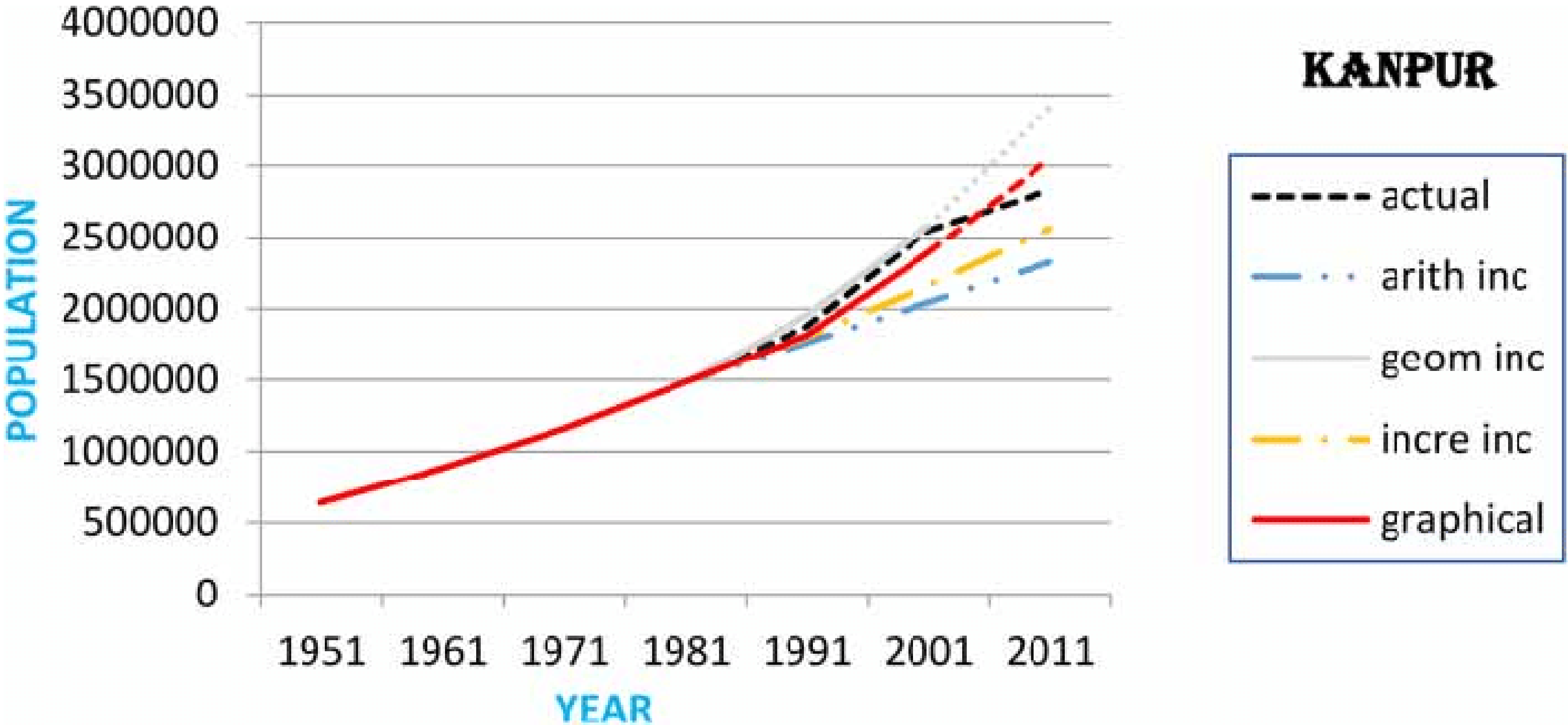
Population estimation

Design of water supply and sanitation scheme is based on the projected population of a particular city, estimated for the design period. Any underestimated value will make system inadequate for the purpose intended; similarly overestimated value will make it costly.

Forecasts are susceptible to error if for no other reason that nobody knows the future. Many methods are used to **forecast** the population in the future. Each method has it’s own assumptions:

- Arithmetic method
- Geometric method
- Ratio method
- Compound method
- Saturation method




KANPUR
POPULATION
4000000
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
1951
1961
1971
1981
1991
2001
2011
YEAR
actual
arith inc
geom inc
incre inc
graphical

Arithmetic method

- Based on the past population data, this method works out an average arithmetic increment in population per time period and uses this increment to forecast the future population.
- Assumption: The rate of change is constant (k)

$$P_f = P_i + k.\Delta t$$

Where:

Pf: final population

Pi: initial population

K: constant

Δt: period difference

Geometric method

•

$$ln\ P_f = ln\ P_i + k.\ \Delta t$$

Where:

ln: natural logarithm

P_f: final population

P_i: initial population

K: constant

Δt: period difference

Example: The recent population of a city is 30,000 inhabitants. What is the predicted population after 30 years if the population increases 4000 in 5 years.

Solution:

K = 4000/ 5 = 800 capita / year

$P_f = P_i + k.\Delta t$

$P_f = 30{,}000 + k * 30$

$P_f = 30{,}000 + 800 * 30$ = 54,000 capita

Example: The recent population of a city is 30,000 inhabitant. What is the predicted population after 30 years if the geometric growth rate is 0.035

Solution:

$ln\ P_f = ln\ P_i + k.\ \Delta t$

$\ln P_f = \ln 30{,}000 + 0.035 * 30$

$\ln P_f = 10.31 + 1.05$

$P_f = 85{,}819$ capita

Example: The past population of a city is given in table below, calculate the population in 2031. using Arithmetic method.

Year	Population
1981	1,240,000
1991	1,510,000
2001	1,760,000
2011	2,025,000

Solution:

K = (27,000+ 25,000 + 26,500)/3 = 26,167 capita / year

$P_f = 2{,}025{,}000 + 26{,}167 * 20$ = 2,548,340 capita

Year	Population	K
1981	1,240,000	
1991	1,510,000	27,000
2001	1,760,000	25,000
2011	2,025,000	26,500

Example: Given the following information about the population of city. Estimate the population at 2030 using Geometric method.

year	population
2000	62,000
2005	74,000
2010	85,000
2015	100,000
2030	?

Solution:

K = (0.0354 + 0.0277 + 0.0325)/3 = 0.0319

$P_f = \ln 100{,}000 + 0.0319 * 15$ = 161,365 capita

year	population	K
2000	62,000	
2005	74,000	0.0354
2010	85,000	0.0277
2015	100,000	0.0325

Example: A small community has a population of 1,000 capita and is growing rate by 1.5% each year. The MDD in the community is 500,000 L/day. What will be the MDD be after 20 years? use Arithmetic method. Neglect fire demand.

Solution:

Current MDD (for one capita) = 500,000/1000 =500 lpcd

$Pf = Pi + K\ t$

= 1000+ (1000x 1.5/100)* 20 = 1300 capita

Future MDD (for community) = 500*1300 = 650,000 l/day

Year	Population
1941	
1951	950,541
1961	1,138,650
1971	1,510,866
1981	1,690,184
1991	1,901,082

Example: A city has 250,000 capita, the average daily demand is 220 lpcd. There are 2 building in the city each of 500 m^2 with 3 stories, the fire would not extend more than 3 hours, calculate the total demand after 20 years if the losses is 15%. The arithmetic growth rate is 10% each ten years. For fire demand use NBFU formula.

Solution:

Growth rate (k) = 10/100 *250,000 /10 = 2500 c/yr

Pf = Pi + K.Δt

Pf =250,000 + 2,500 *20 = 300,000 capita

Q=4080√pX(1−0.01√p) = 4080* √300(1-0.01*√300) = 58,428 l/min

It mentions the fire will not extend more than 3 hours, so

Fire requirement = 58,428 *(60*24) *(3/24) = 10,517,040 l/d

Maximum daily demand = average daily demand * factor

MDD = 220 * 300,000 * 1.8 = 118,800,000 L/d

PHD = 220 * 300,000 * 2.7 = 178,200,000 L/d

Losses =0.15 from the total

Total required by water treatment plant = (MDD + Fire requirement) * 1.15
= 148,714,596 L/d

Total required by distribution system = (PHD + Fire requirement) *1.15
= 217,024,596 L/d

Ratio method

$$\frac{P_{fR}}{P_f} = \frac{P_{iR}}{P_i}$$

Where:

PfR: number of future population for the area under study

PiR: number of population for the area under study

Pf: number of future population for the whole area

Pi: number of population for the whole area

Compound method

It is the most accurate and complex method

$$P_f = P_i * e^{k.\Delta t}$$

$$r = (b-d) + (i-o)$$

Where:

P_f :future population

P_i : present population

k : r/ P_i

t: time

b: birth rate

d: death rate

i: immigration to the city under study

o: immigration out of the city under study

Saturation method

$$P = P_i + (S - P_i)(1 - e^{-K.\Delta t})$$

Where:

P = population

t = time

k = decreasing rate of increase growth constant

S = Saturation population

Note: the saturation population is the maximum number of people can inhabit a town based on the physical constraints of buildable land zoning

Example: The population of a city A in 1990 was 51,000 capita. Estimate the population of city A in year 2025. The growth rate of city A is similar to city B.

City A		City B	
Year	Pop. * 1000	year	Pop. * 1000
1970		1970	69
1980		1980	80
1990	51	1990	93
2000		2000	110

Solution

First calculate the growth rate of city B, then the population of city B in 2025

If did not mention in the question the method must use then choose the method you want, let say Arithmetic method

Growth rate (k1) = (80000-69000)/ (1980-1970) = 1100 c/y

K2= (93000-80000)/ (10) = 1300 c/y

K3= (110000-93000)/ (10) = 1700 c/y

Average K= 1367 c/y

P2025= P2000 + K.t

P2025= 110,000 + 1367 *25 = 144,175 c

Calculate the population of city A in 2015 by ratio method due similarity with city B

$$\frac{Pop\ (A)2025}{Pop\ (B)2025} = \frac{Pop\ (A)1990}{Pop\ (B)1990}$$

Pop (A) 2025 = 51,000* 144,175/93,000 = 79,064 c

R = (80 -30) + (0- 5) = 45 c/d = 16,425 c/y

Unit of k must be (1/year), so divided by the population

k = 16,425/ 5,000,000 = 0.00328 1/y

$P_f = P_i * e^{(k.\,\Delta t)}$

$P2020 = 5{,}000{,}000 * e^{(0.00328 * 5)} = 5{,}082{,}676$ capita

Example: The population in 1990 of city A was 110,500 capita, in 2000 the population was 118,200, assume Saturation limit for city A is 250,000, K= 0.00568. Calculate the population in 2025.

Solution

$P = P_1 + (S-P_1)(1- e^{-K*\Delta t})$

P_{2025} = 118,200+ (250,000-118,200) $(1-e^{-0.00568*25})$ =135,648 capita

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Water Pollution

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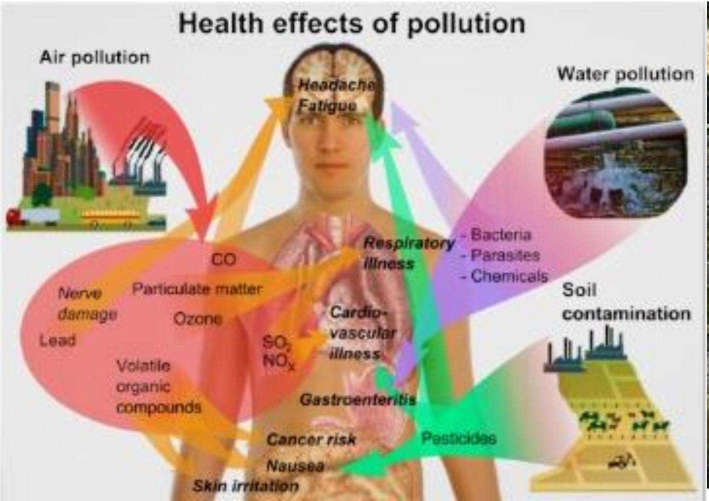
Pollution

- Pollution is the introduction of a contaminants/ pollutants into the environment. It is created by industrial and commercial waste, agricultural practices, everyday human activities that cause adverse change to human health and environment.
- Pollution can take the form of biological creatures, chemical substances or energy, such as noise, heat and radiation.



The are three types of pollution:

- Land Pollution
- Air Pollution, Ex: London Great Smog 1952
- Water Pollution, Ex: London Great Stink 1858



Type of wastes according to its sources

- Domestic waste: food residual, human waste, grease, oil, detergents.
- Industrial waste: to the industry such as petroleum from oil well.
- Agricultural pesticide, herbicide
- Hospital waste: mainly viruses, bacteria

Waste source

- Point Source: discharge of pollutants from single point. Factories, power plants, sewage treatment plants, oil wells.
- Non-point Source: sources of water pollution that are scattered or diffuse, not having a specific location. Farm fields, cities, roads, clear-cut forests, mines.



Water pollution

- Water is considered polluted if some substances or condition is present to such a degree that the water cannot be used for a specific purpose.
- Water pollution is the presence of excessive amounts of a hazard (pollutants) in water in such a way that it is no long suitable for drinking, bathing, cooking or other uses.
- Physical, chemical, biological changes in water quality that adversely affect living organisms, human and environment.

Types of water pollution

- Color
- Taste and Odor
- Temperature
- pH scale (acid & base)
- Sediment (Particulates)
- Microorganisms: Infectious Agents
- Inorganic Pollutants
- Organic Chemicals (non domestic waste)
- Oxygen-Demanding Wastes (domestic waste)
- Radiation

Color

- Color in water is caused by substances in solution, known as true color, and by substances in suspension, mostly organics, known as apparent or organic color.
- Iron, copper, manganese, and industrial wastes all can cause color.
- Color is aesthetically undesirable, and it stains fabrics and porcelain bathroom fixtures.
- Water color is determined by comparison with standard platinum/cobalt solutions or by spectrophotometric methods.
- The IS value for treated water is 5 to 25 cobalt units.

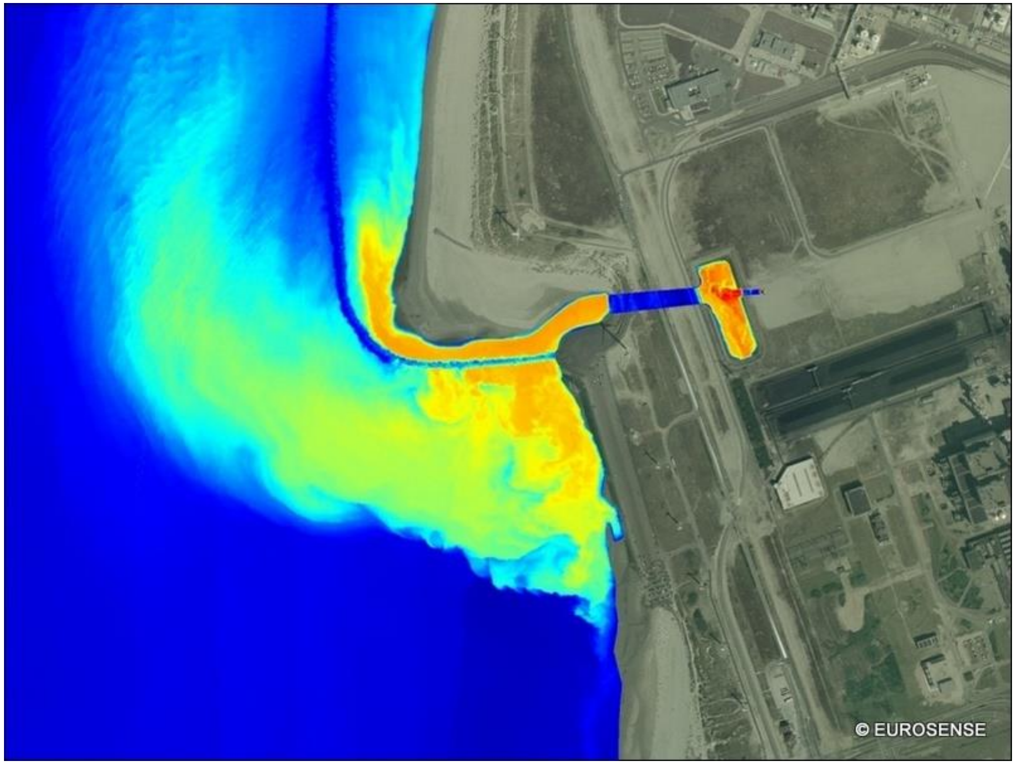
Taste and Odor

- Odor depends on the contact of a stimulating substance with the appropriate human receptor cell.
- Most organic and some inorganic chemicals, originating from municipal or industrial wastes, contribute taste and odor to the water.
- Tas ed in term odor intensity or threshold values.
- A new method to estimate taste of water sample has been developed based on flavor known as " Flavor Profile Analysis" (FPA).
- The character and intensity of taste and odor discloses the nature of pollution or the presence of microorganisms.

Temperature

- The increase in temperature decreases palatability, because at elevated temperature carbon dioxide and some other volatile gases are expelled.
- The ideal temperature of drinking water is 5 to 12˚C, above 25˚ C water is not recommended for drinking.

- Thermal Pollution: an increase in water temperature
- Source: Nuclear power plants, coal power plants, industrial effluents, domestic sewage.
- Can cause: thermal shock to aquatic life.

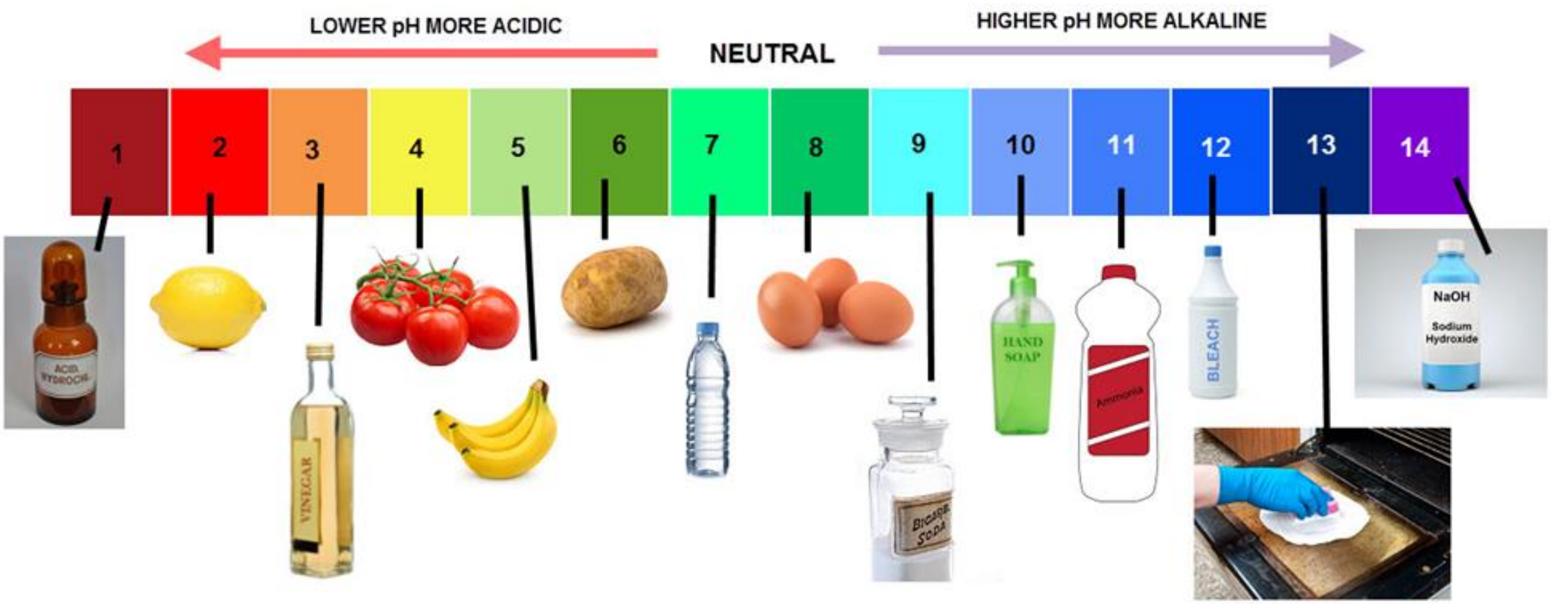


Acid and base

- Affect the degree of corrosion of metals as well as disinfection efficiency
- The pH of the water entering the distribution system must be controlled to minimize the corrosion of pipes in household water systems. Failure to do so can result in the contamination of drinking-water and in adverse effects on its taste, odor.

- *Acid rain* describes a mixture of wet and dry atmospheric deposition containing higher than normal amounts of nitric and sulphuric acids.
- The chemical compounds of acid rain result from both natural sources, such as volcanoes and decaying vegetation, and from manufactured sources, primarily sulphur dioxide (SO_2) and nitrogen oxide (NOx) emissions from fossil fuel combustion.
- Acid rain is associated with the acidification of soils, lakes, and streams, accelerated corrosion of buildings and monuments, and reduced visibility.
- In the United States, about two-thirds of all SO_2 and one-quarter of all NOx come principally from coal burning power plants.
- Acid rain occurs when SO_2 or NOx gases react in the atmosphere with water, oxygen, and other chemicals to form mild solutions of sulphuric or nitric acid.

- pH is a way of expressing the hydrogen-ion concentration of a solution. As acids and bases in solution dissociate to yield hydrogen ions [H+] and hydroxyl ions [OH^-] respectively, pH is the acidic or alkaline condition of a solution.
- pH =-log[H]

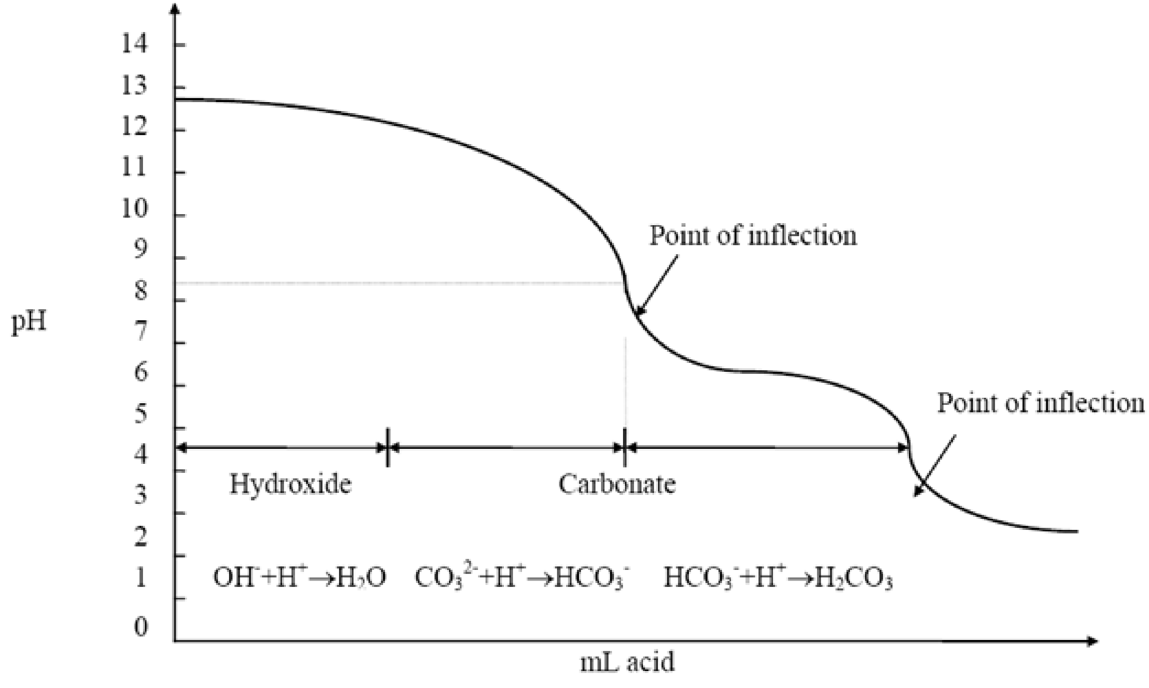


- The alkalinity of water is its quantitative capacity to neutralize acids. The three major forms of alkalinity ranked in order of their association with high pH values are

(1) hydroxide $[OH^-]$

(2) carbonate, $[CO_3^{-2}]$

(3) bicarbonate $[HCO_3^-]$



Type of Impurities in Water

- **Suspended**
  - **Soil**
    - Sand
    - Silt
    - Clay
    - Colloidal
  - **Microorganisms**
    - Bacteria
    - Algae
    - Fungi
    - Protozoa
    - Viruses
- **Dissolved**
  - **Salts**
    - **Cation**
      - Ca
      - Mg
      - Mn
      - Fe
      - Na, K
      - Pb, Hg
    - **Anion**
      - HCO_3
      - CO_3
      - SO_4
      - Cl
      - F
      - NO_3, NO_2
  - **Gases**
    - O_2
    - CO_2
    - H_2S
    - CH_4
    - N_2
    - NH_3
  - **Organic Matter**

Suspended Impurities	Causes
Bacteria	Disease
Algae	Odor, Color, Turbidity
Protozoan	Disease
Viruses	Disease
Silt	Murkiness & Turbidity
Clay	Murkiness & Turbidity
Colloids	Color, Murkiness & Turbidity

Gases	Causes
Oxygen	Corrosive, Oxidizing agent
Carbon Dioxide	Acid
Hydrogen Sulfide	Acid, Reducing agent
Ammonia	Caustic

Salts-Cations	Causes
Calcium	Hardness
Magnesium	Hardness
Iron	Hardness, Color
Manganese	Hardness, Color
Others	Dissolved Solids

Salts-Anions	Causes
Bicarbonate	Alkalinity
Carbonate	Alkalinity
Sulfate	Laxative
Chloride	Taste
Fluoride	Tooth Mottling
Organics	Color, Taste, Odor, Toxicity

Impurities of water may be divided into two classes:

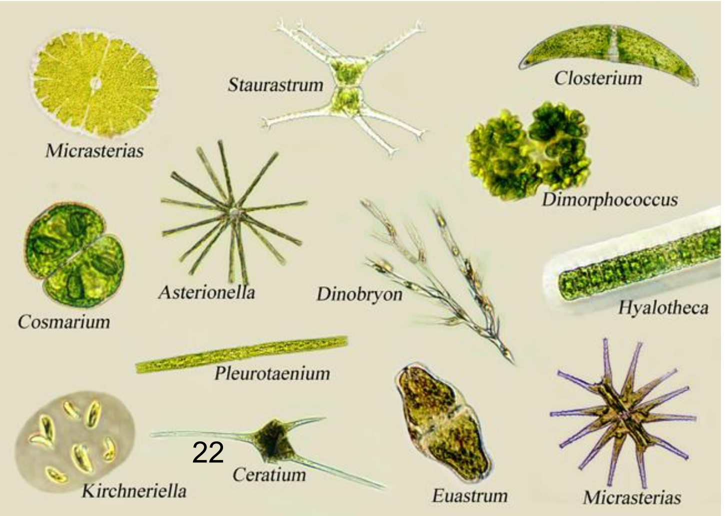
1. Suspended Impurities:

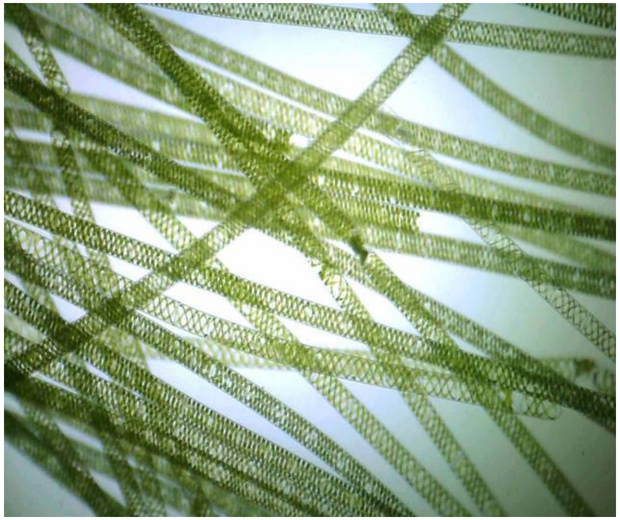
- Microorganisms: they may get into water from air with dust, etc., as r only when soil polluted with human and animal wastes washed into the water source.
- The latter type of impurities in water is the most dangerous one because a good number of microorganisms are pathogenic and cause diseases.
- Microorganisms such as bacteria, algae, fungi, etc.

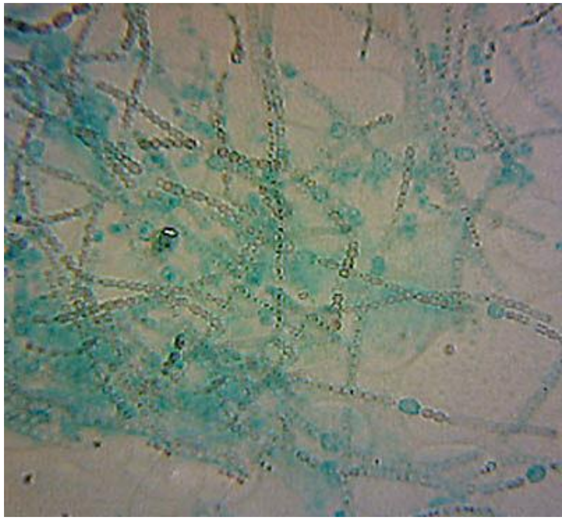
- Algae: Algae are minute plants that grow in still or stagnant water. Some algae are green, brown or red, and their presence in water causes taste, color and turbidity.
- Some species of algae could be poisonous both for aquatic animals and humans.

There are different types of algae found in water:

- Asterionella: gives water an unpleasant odor.
- Spirogyra: is a green scum found in small ponds and polluted water. It grows in thread. It is slippery and non-toxic.
- Anabaena: is blue- green and occurs in fishponds, pools, reservoir and clogs filter

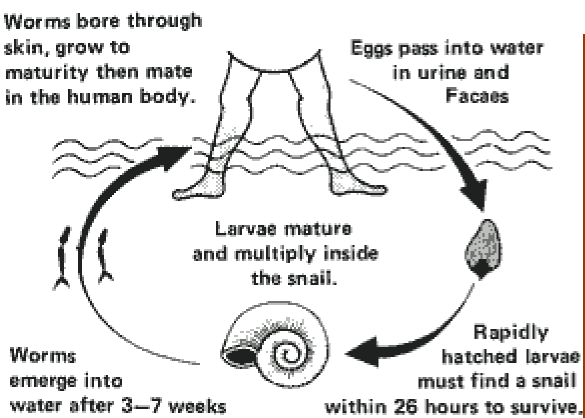


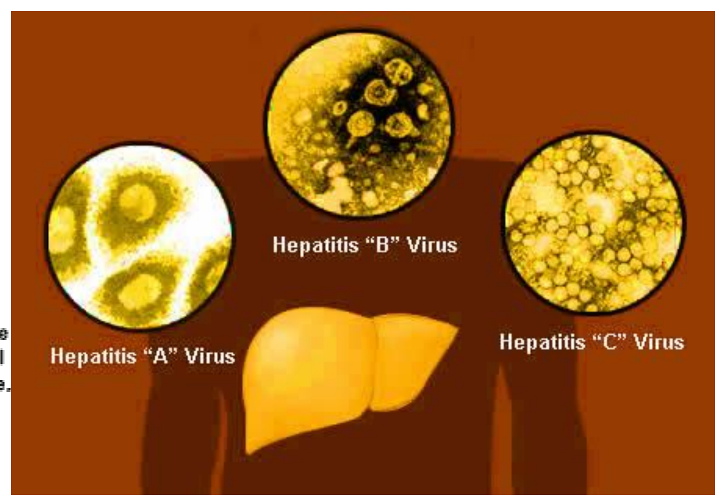




Infectious Agents: Bacteria

- Infectious Agents : pathogenic organisms. Water-borne diseases include typhoid, cholera, bacterial and amoebic dysentery, infectious hepatitis, guinea worm and bilharzia.
- Due to lack of sanitation, analyze coliform bacteria (E. coli). Presume if coliform bacteria are present, infectious pathogens are also present.





Some human diseases transmitted by polluted water

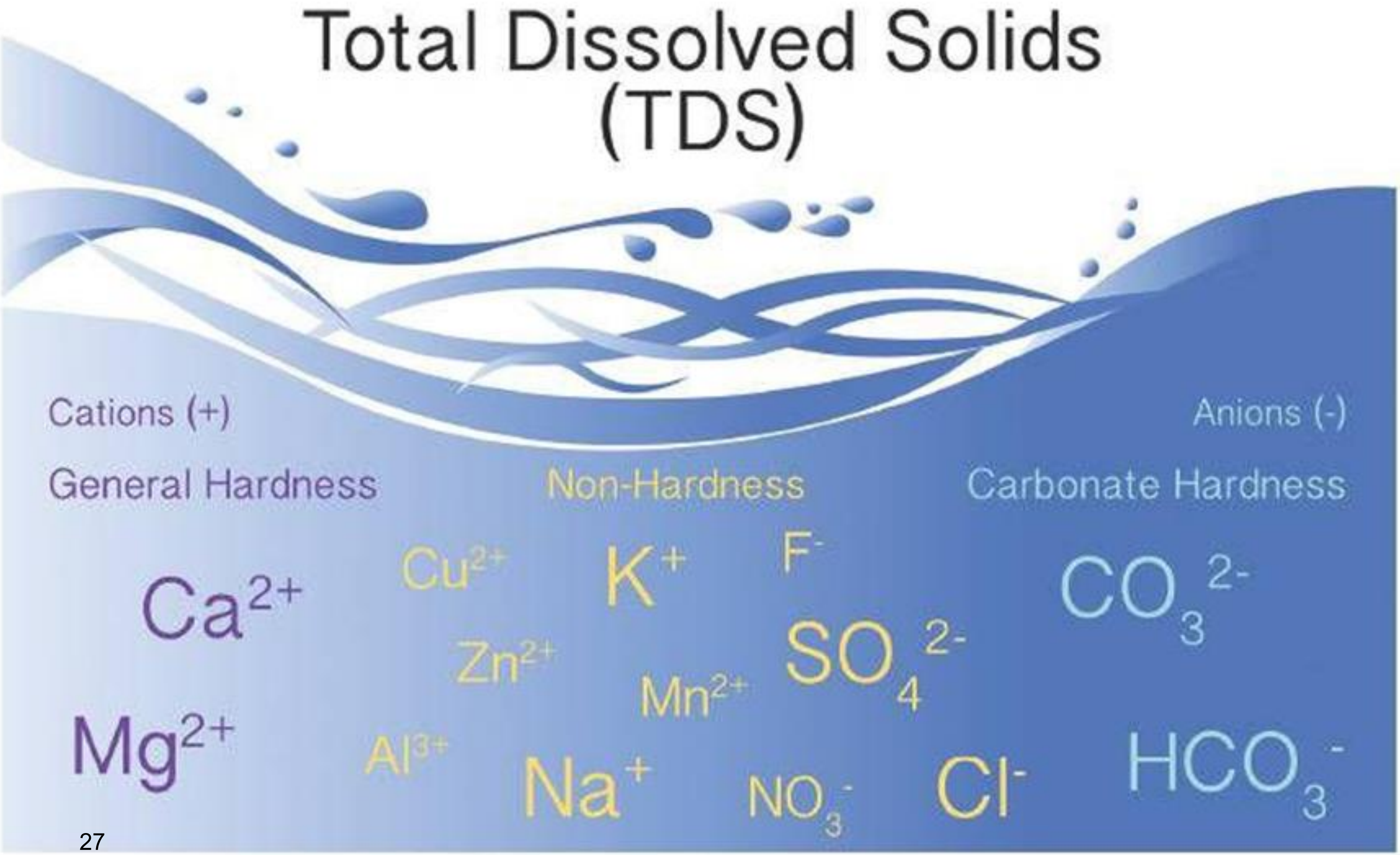
Disease	Infectious Agent	Type of Organism	Symptoms
Cholera	*Vibrio cholerae*	Bacterium	Severe diarrhea, vomiting; fluid loss of as much as 20 quarts per day causes cramps and collapse
Dysentery	*Shigella dysenteriae*	Bacterium	Infection of the colon causes painful diarrhea with mucus and blood in the stools; abdominal pain
Enteritis	*Clostridium perfringens*, other bacteria	Bacterium	Inflammation of the small intestine causes general discomfort, loss of appetite, abdominal cramps, and diarrhea
Typhoid	*Salmonella typhi*	Bacterium	Early symptoms include headache, loss of energy, fever; later, a pink rash appears along with (sometimes) hemorrhaging in the intestines
Infectious hepatitis	Hepatitis virus A	Virus	Inflammation of liver causes jaundice, fever, headache, nausea, vomiting, severe loss of appetite; aching in the muscle occurs
Poliomyelitis	Poliovirus	Virus	Early symptoms include sore throat, fever, diarrhea, and aching in limbs and back; when infection spreads to spinal cord, paralysis and atrophy of muscles
Cryptosporidiosis	*Cryptosporidium* sp.	Protozoon	Diarrhea and cramps that last up to 22 days
Amoebic dysentery	*Entamoeba histolytica*	Protozoon	Infection of the colon causes painful diarrhea with mucus and blood in the stools; abdominal pain
Schistosomiasis	*Schistosoma* sp.	Fluke	Tropical disorder of the liver and bladder causes blood in urine, diarrhea, weakness, lack of energy, repeated attacks of abdominal pain

Sediment

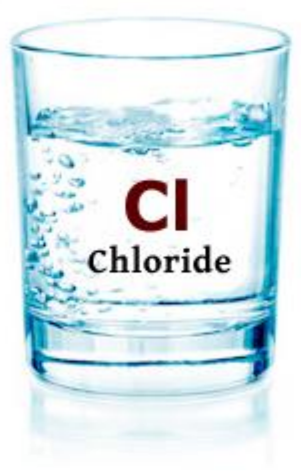
- Sediment is the loose sand, clay, silt and other soil particles that settle at the bottom of a body of water.
- Source: soil erosion and runoff, decomposition nd animals.
- Cause: obstructs shipping channels, clogs pipes, purification more costly, disinfection process is not efficient.

- Turbidity is caused by suspended materials which absorb and scatter light, such as clay, silt, finely divided organic and inorganic matter, plankton and other microscopic organisms.
- These materials are typically in the size range of 0.004 mm (clay) to 1.0 mm (sand). Turbidity can affect the color of the water.
- These colloidal and finely dispersed turbidity-causing materials do not settle under quiescent conditions and are difficult to remove by sedimentation.
- Turbidity is a key parameter in water supply engineering, because turbidity will both cause water to be unpleasant and cause problems in water treatment processes, such as filtration and disinfection.
- Turbidity is also often used as indicative evidence of the possibility of bacteria being present.

2. Dissolved Impurities:



- Chlorides (Cl^-): may be present in combination with one or more of the cations of calcium, magnesium, iron and sodium.
- Chlorides of these minerals are present in water because of their high solubility in water.
- Each human being consume about 6 to 8 grams of sodium chloride (NaCl) per day, a part of which is discharged through urine.
- Thus excessive presence of chloride in water indicates sewage pollution.
- IS value for drinking water is 250 to 1000 mg/l.



- Sulphates (SO_4^{-2}): occur in water due to leaching from sulphates mineral and oxidation of sulphide.
- Sulphates are associated generally with calcium, magnesium and sodium ions.
- Sulphate in drinking water causes a laxative effect and leads to scale formation in boilers.
- It also cause odor and corrosion problems under aerobic conditions.
- Desirable limit for drinking water is 150 to 400 mg/l.

- Iron (Fe): is found on earth mainly as insoluble ferric oxide.
- When it comes in contact with water, it dissolves to form ferrous bicarbonate under favorable conditions. This ferrous bicarbonate t bad taste to the water, causes discoloration in clothes.
- IS value for drinking water is 0.3 to 1 mg/l.

- Nitrates (NO_3^-): in surface water occur by the leaching of fertilizers from soil during surface run-off and also nitrification of organic matter.
- Presence of high concentration of Nitrates is an indication of pollution.
- Concentration of nitrates above 45 mg/l causes a disease methemoglobin. IS value is 45 mg/l.

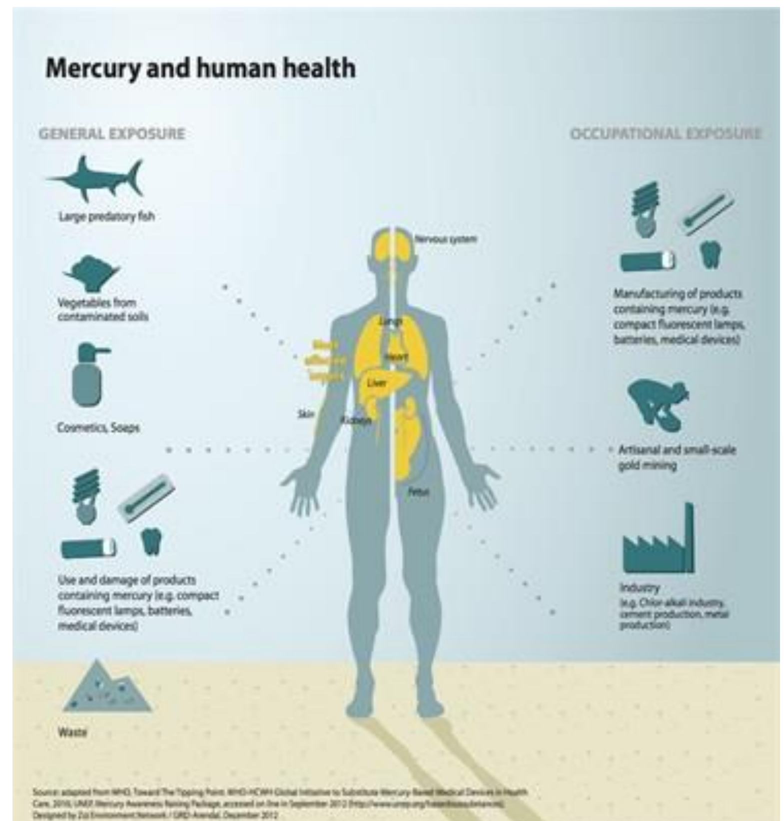
Mercury (Hg^{+2}) Cation, metallic:

Source:

- Industry such as (fluorescent light bulbs), cement and steel
- Coal-fired power plants,
- Incineration,
- Natural sources, such as volcanoes

Causes:

- Damage to the nervous system
- Development delays
- kidney disorders



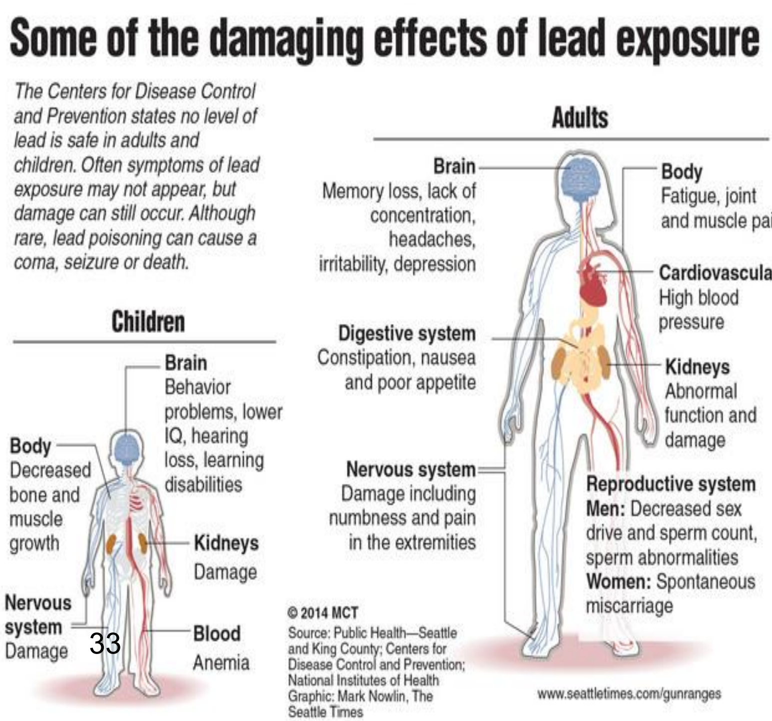
Lead (Pb^{+2}) Cation, metallic:

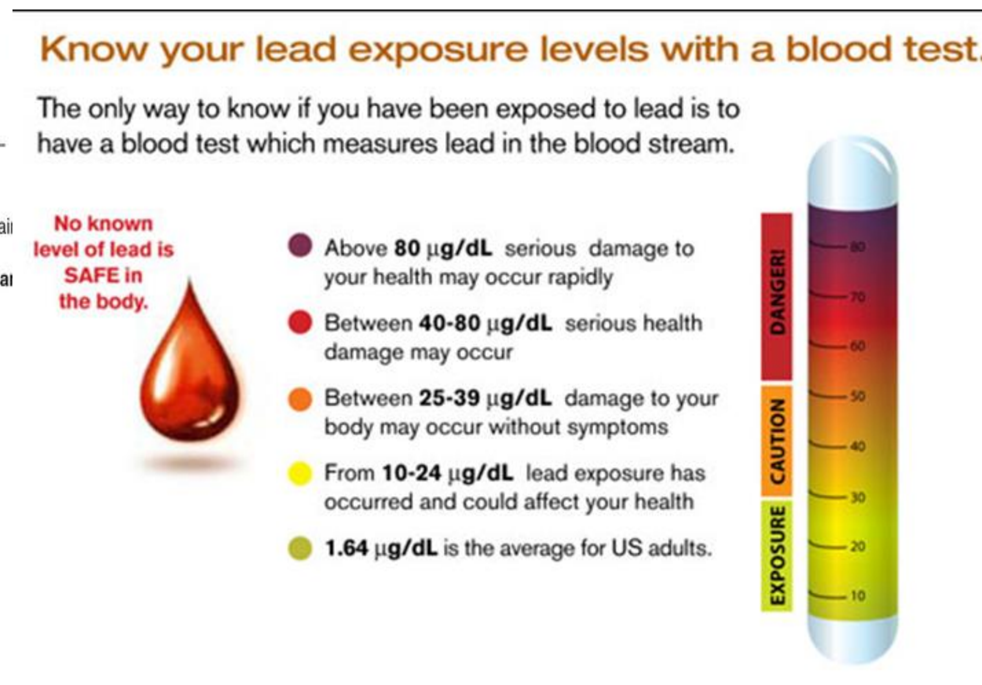
Source

Incineration, pipes, solder, gasoline

Causes:

Nervous system, anemia, abortion, Hearing los

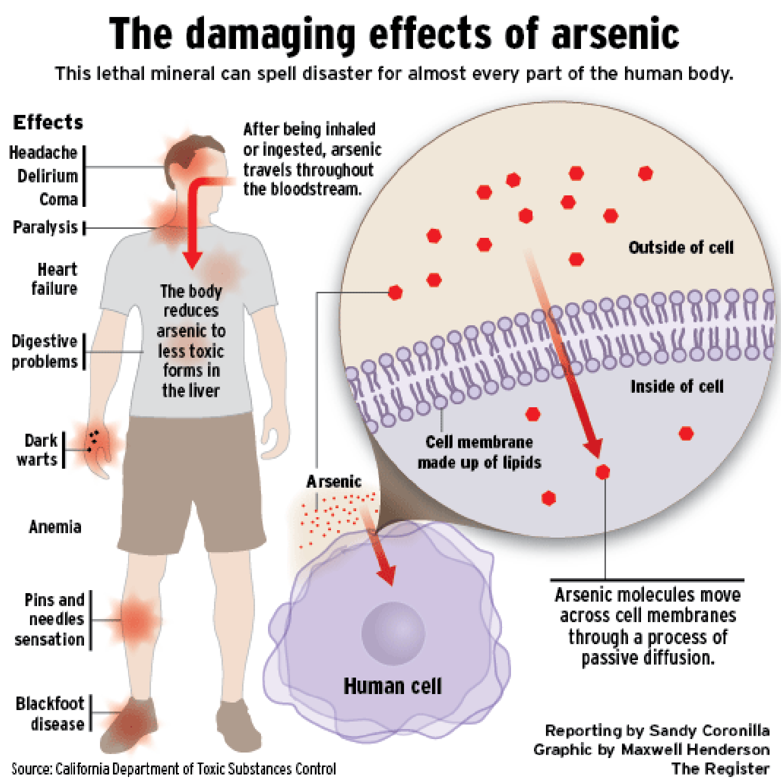




Arsenic (As^{+3}) cation, Non metal:

Source: Industries, mining, pesticides, ground water

Causes: anemia, cancer



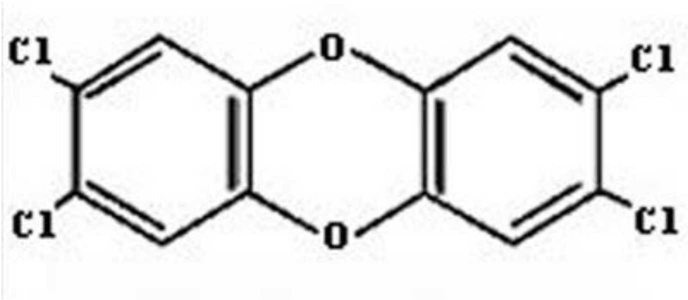
Hardness

- If water consumes excessive soap to produce lather, it is said to be hard.
- Hardness is caused by divalent metallic cations.
- The principle hardness causing cations are calcium, magnesium, strontium, ferrous and manganese ions.
- Major anions associated with these cations are sulphates, carbonates, bicarbonates, chlorides and nitrates.
- Total hardness of water is defined as the sum of calcium and magnesium concentration, both expressed as **calcium carbonate**, in mg/l.
- Hardness are of two types, temporary or carbonate hardness and permanent or non-carbonate hardness.
- Temporary hardness is one in which bicarbonate and carbonate ion can be precipitated by prolonged boiling.
- Non-carbonate ions cannot be precipitated or removed by boiling
- IS value for drinking water is 300 mg/l as $CaCO_3$.

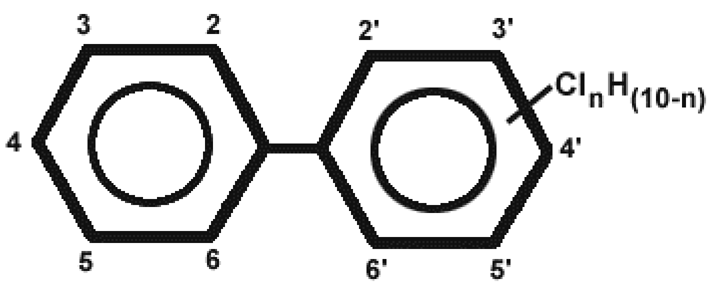
Organic Pollutants

- Such as pesticides, solvents, pharmaceuticals, and industrial chemicals
- In 1995, the United Nations Environment Programme Governing Council investigated. Initially the Convention recognized only 12 POPs for their adverse effects on human health and the environment, placing a global ban on these particularly harmful and toxic compounds and requiring its parties to take measures to eliminate or reduce the release of POPs in the environment. Such as Dioxin, PCB, DDT.
- Since 2001, this list has been expanded to include certain polycyclic aromatic hydrocarbons (PAHs) and other compounds.

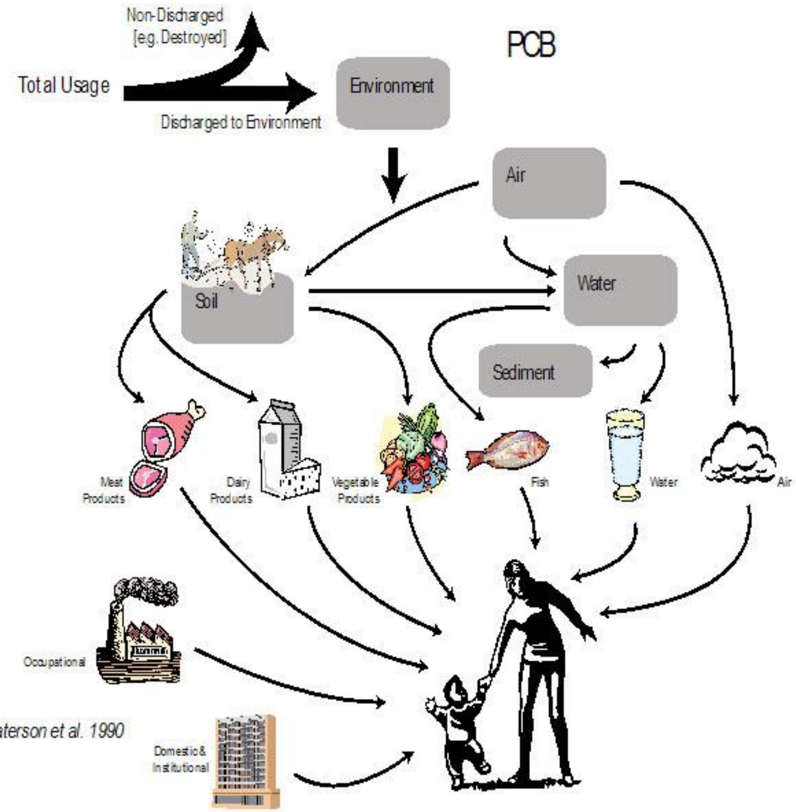
- Dioxin : Stable; slow to degrade
- Generated from : Burning wood, coal, oil, household trash, and chlorine bleaching of paper.
- Causes : Damage the immune system, interfere with hormones and also cause cancer.



- Polychlorinated Biphenyl (PCBs) : stable, non-flammable, high boiling points.
- Does not conduct electricity well, so used in electr Accumulates in fat of animals
- Causes: hormonal and reproductive disruptions, cancer.

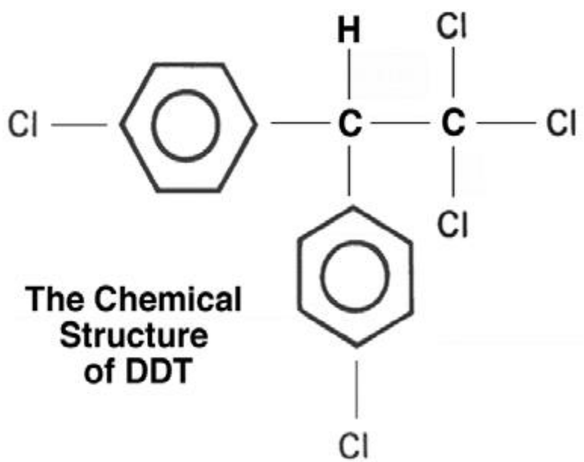


Polychlorinated Biphenyl (PCB)

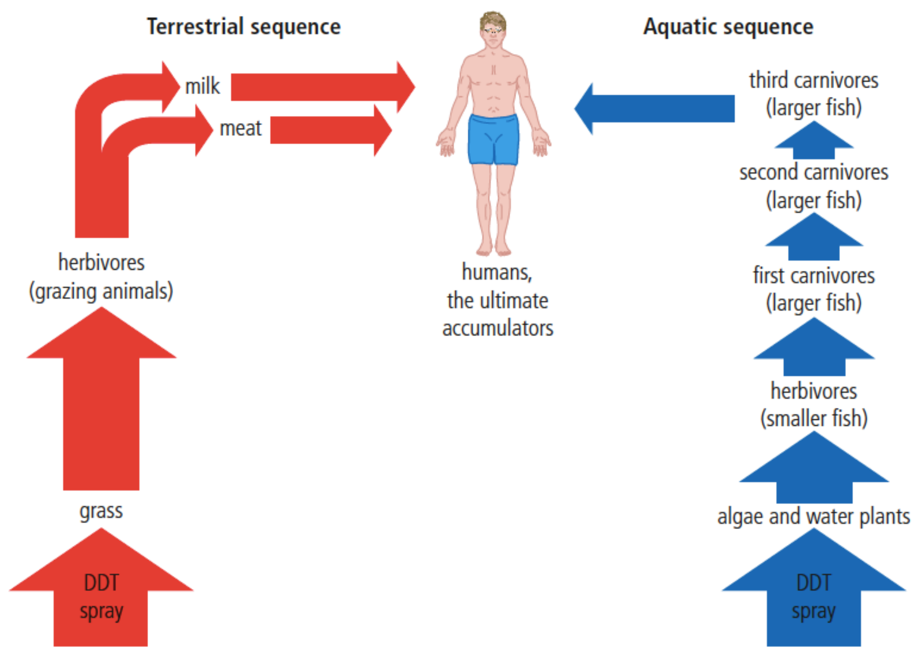


Source: Paterson et al. 1990

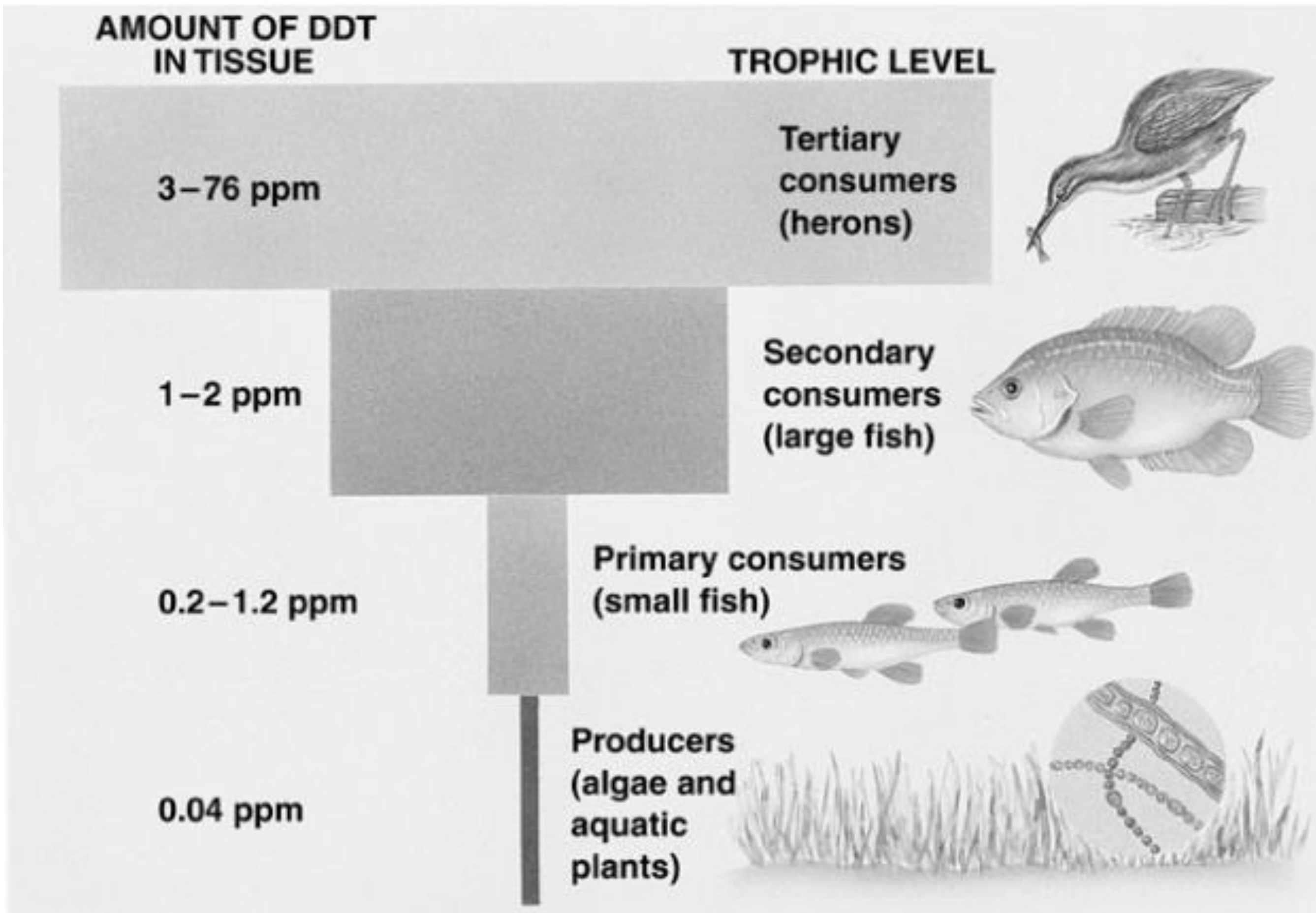
- DDT : insecticide; stable and slow to degrade.
- Paul Muller won the Nobel Prize in 1948 for developing it. Benefits: Controlled spread of malaria; Provided crop protection.
- Cause: decreased mental function, male infertility, cancer



The Chemical Structure of DDT

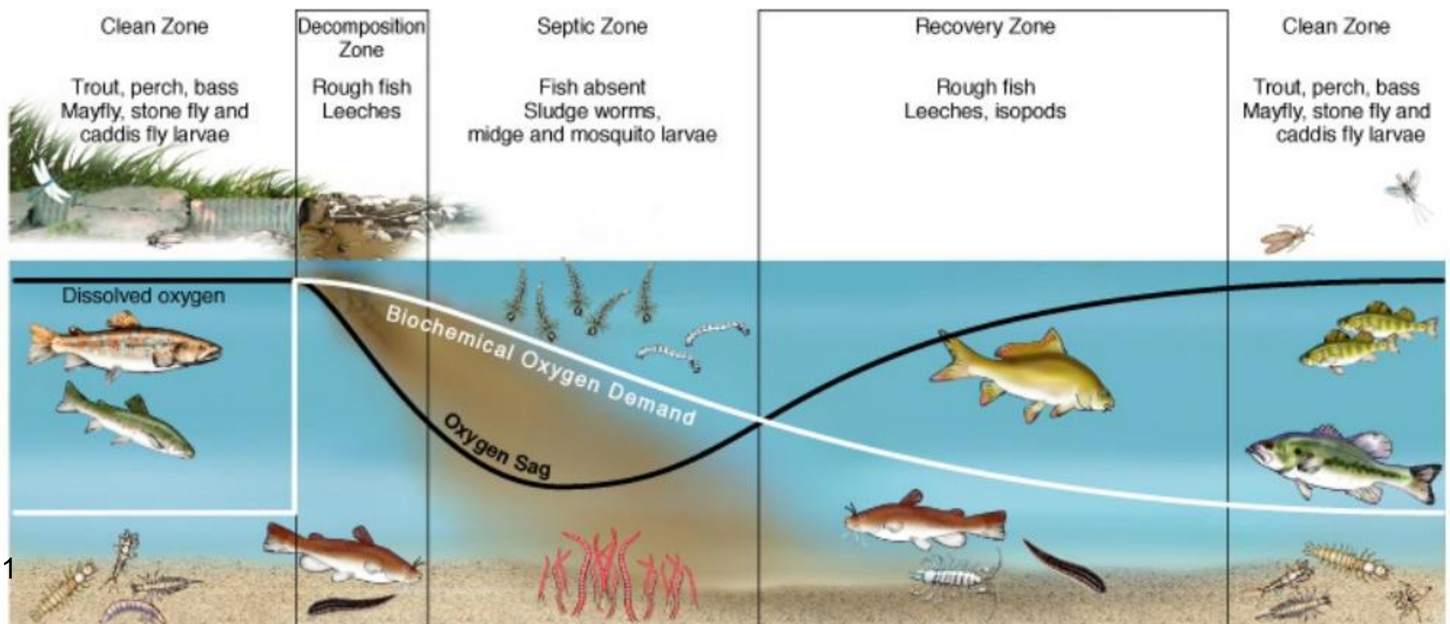


- Problems with DDT: DDT is not metabolized very rapidly by animals; instead, it is deposited and stored in the fatty tissues bioaccumulation.



Oxygen-Demanding Wastes

- Oxygen dissolved in water is indicator of water quality. 6 part per million (ppm) of O_2 or more supports desirable aquatic life.
- BOD: Biochemical oxygen demand : measures the amount of dissolved oxygen consumed by aquatic microorganisms.
- Sewage or food wastes can cause an Oxygen sag, where few fish survive.



Biochemical oxygen demand (BOD)

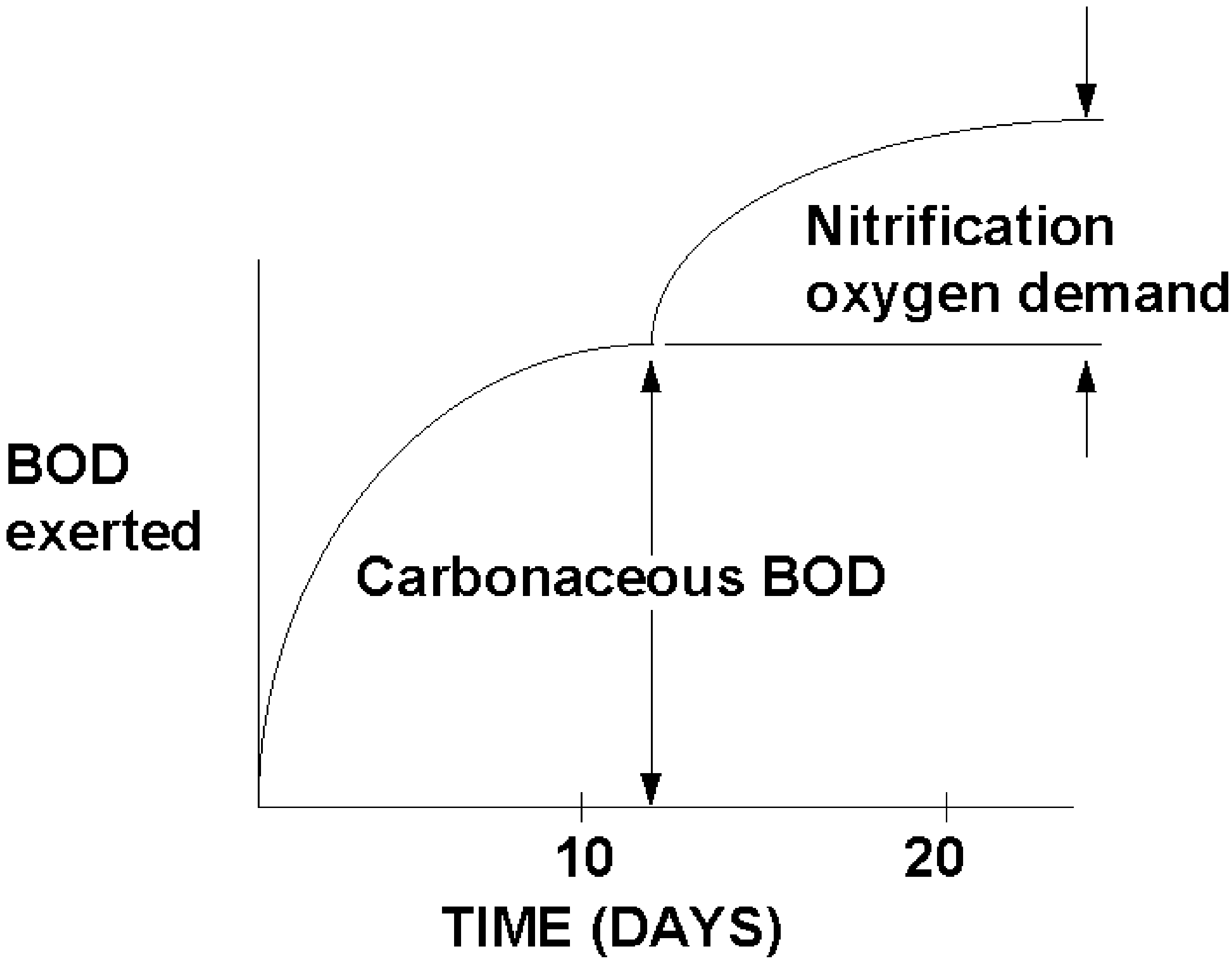
- BOD is the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period depending on temperature, nutrient concentrations, and the enzymes available to indigenous microbial populations.
- The BOD value is most commonly expressed in milligrams of oxygen consumed per liter (mg/l) of sample during 5 days of incubation at 20 °C and is often used as a indicator of the degree of organic pollution of water and effectiveness of wastewater treatment plants.
- BOD is similar in function to chemical oxygen demand (COD), in that both measure the amount of organic compounds in water. However, COD is less specific, since it measures everything that can be chemically oxidized, rather than just levels of biologically active organic matter.

- Most natural waters contain small quantities of organic compounds. Aquatic microorganisms have evolved to use some of these compounds as food.
- Microorganisms living in oxygenated w ic community can produce.
- Fish and aquatic insects may die when oxygen is depleted by microbial metabolism.

Organic matter + O_2+ bacteria → CO_2 + H_2O + new cells of bacteria

Organic nitrogen + O_2 + bacteria → Ammonia-nitrogen

NH_3-N +O_2 → Nitrate- nitrogen (NO_3-N) (nitrification)



- Dissolved oxygen (DO) depletion is most likely to become evident during the initial aquatic microbial population explosion in response to a large amount of organic material.
- Most rivers will have a 5-day carbonaceous BOD below 1 mg/L.
- Moderately polluted rivers may have a BOD value in the range of 2 to 8 mg/L.
- Municipal sewage that is efficiently treated averages around 600 mg/L in Europe and as low as 200 mg/L in the U.S., or where there is severe groundwater or surface water Infiltration/Inflow. The generally lower values in the U.S. derive from the much greater water use per capita than in other parts of the world.

Typical values of k & BOD ultimate (L) for various waters for default temperature of 20°C

Water Type	K (Day^{-1})	L_0 (mg/l)
Tap water	<0.1	0 – 1
Surface water	0.1 – 0.23	1 – 30
Weak municipal waste water	0.35	150
Strong municipal waste water	0.40	250
Treated effluent	0.12 – 0.23	10 – 30

$$BOD_t = BODu(1 - e^{-k.t})$$

Where:

BOD_t: BOD at any time (mg/l)

BOD_u: BOD ultimate (mg/l)

e: exponential

t: Time (day)

K: reaction constant (1/day), depend on temperature

$$K_{temp} = K_{20C}.\, \theta^{temp-20}$$

ɵ = 1.135 for 4 < Temp ≤ 20°C

ɵ = 1.056 for Temp > 20°C

BOD_5 is calculated by:

Unseeded BOD_5 = $\frac{DO_i - DO_5}{p}$

Seeded BOD_5 = $\frac{(DOi - DO_5) - (BOi - BO_5).f}{p}$

where:

DO_i is the dissolved oxygen (DO) of the diluted solution after preparation (mg/l)

DO_5 is the DO of the diluted solution after 5 day incubation (mg/l)

p is the decimal dilution factor

BO_i is the DO of diluted seed sample after preparation (mg/l)

BO_5 is the DO of diluted seed sample after 5 day incubation (mg/l)

f is the ratio of seed volume in dilution solution to seed volume in BOD test on seed

- 60- 70 % of the oxidation/ degradation of organic pollutants in 5 days
- 95- 99% oxidization in 20 days

Example: Determine BOD_1 & BOD_u for waste water where BOD_5 at 20˚C is 200 mg/l, k= 0.23 d^{-1}

Example: Water sample has 0.02 dilution factor (1 ml from sample diluted in 50 ml distilled water), the initial dissolved oxygen (DO) is 10 mg/l, after 5 days the DO is 6 mg/l. Calculate BOD_5

Thomas Graphical Method (McGhee 1991): This is an approximate method. It is based on the following equation:

$$(t/y)^{1/3} = 1/(2.3\ kL_0)^{1/3} + [(2.3\ k)^{2/3}/6\ L_0^{1/3}]\ .\ t$$

$$Z = a + b.\ t$$

Where:

a: intercept with y axis

b: line slop (dy/dx)

Sample calculation

Step 1: calculate $(t/y)^{1/3}$

Time (t)	BOD_t (y)	$(t/y)^{1/3}$
0	0.00	---
1	1.60	0.855
2	3.0	0.873
3	3.86	0.919
4	4.74	0.945
5	5.14	0.991
6	6.86	0.956
7	7.74	0.967

step 2: Plot $(t/y)^{1/3}$ versus "t" and found slope and intercept

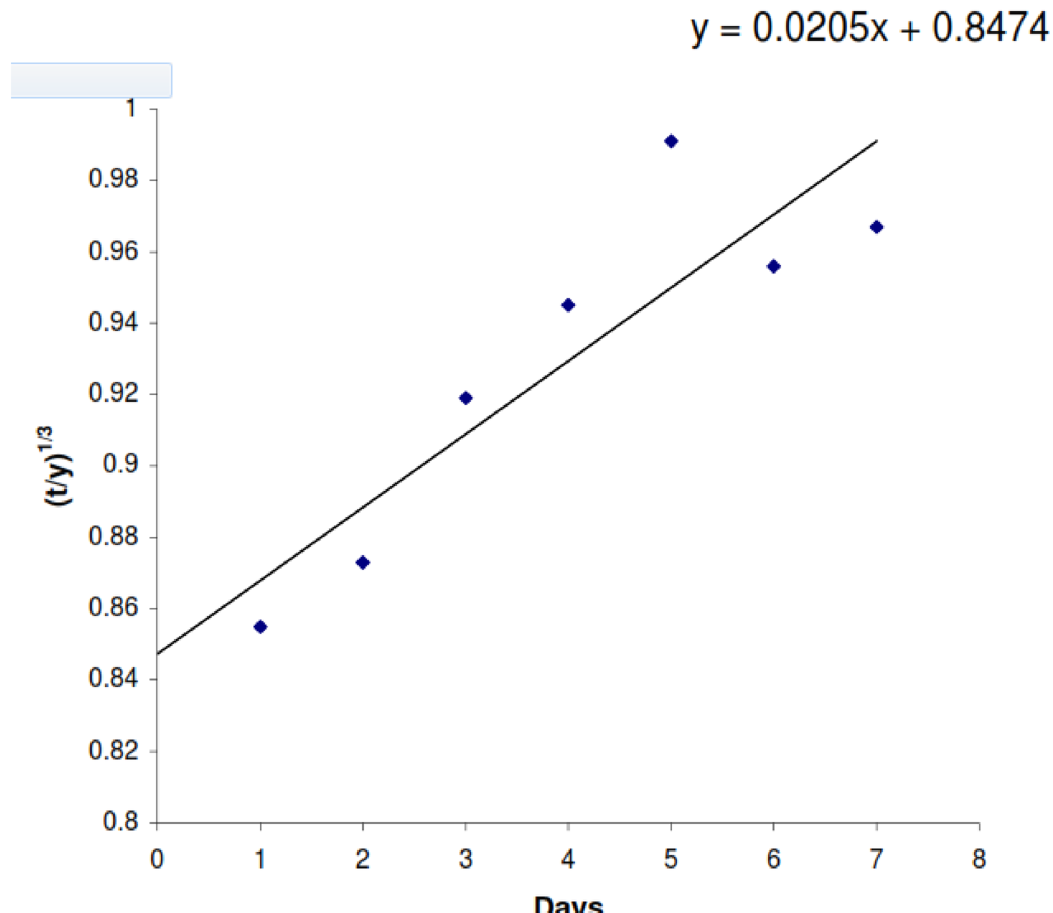
Slope = 0.0205

Intercept = 0.8474

Step 3: k and L

$$K = 2.61\,\frac{slope}{intercept} = 0.063/\text{day}$$

$$L = \frac{1}{2.3*k*intercept^3} = 11.34\ \text{mg/l}$$



HW: Compute the value of k & BOD_u for the data given below

Time (day)	BOD_t (mg/l)
2	11
4	13
6	22
8	24
10	26

Treatment evaluation

$$\text{Efficiency (BOD)} = \frac{\mathrm{BOD_{inf}} - \mathrm{BODeff}}{\mathrm{BOD_{inf}}} \times 100$$

BOD: Biological oxygen demand

inf: Influent (flow in)

eff: Effluent (flow out)

Example: the plant efficiency of treatment plant are 50% for BOD & 70% for suspended solid (SS), BOD & SS of wastewater enter the plant are 40 & 55 mg/l, respectively. Can we dispose the flowing out from the treatment plant to the river? Why?

Radiation

- *Radon* is a radioactive noble gas formed by the natural decay of uranium, which is found in nearly all soils.
- Radon is considered a health hazard amination inside of homes is of particular concern and cannot be remedied once detected.

- Radon concentrations in the air are typically expressed in units of picocuries per liter (pCi/L) of air. Concentrations can also be expressed in *working levels* (WL) rather than picocuries per liter (1 pCi/L = 0.004 WL).

	مواصفات هيئة الصحة العالمية	مواصفات الاتحاد الأوربي	المواصفات الكندية	المواصفات الأمريكية	المواصفات الروسية
اللون TCU	15	20	15	15	-
المواد الصلبة الذائبة	1000	-	500	500	-
المواد الصلبة المعلقة	-	-	-	-	-
العكارة NTU	5	4	5	1 – 5	-
الاس الهيدروجينى PH	6.5 – 8.5	6.5 – 8.5	8.5 – 6.5	8.5-6.5	-
الأكجسين المذاب	-	-	-	-	4
عسر الماء	500	-	-	-	-
نيتروجين نشادرى (امونيا)	-	-	-	-	2
الأمونيوم	-	0.5	-	-	2
نترات معين بالنيتروجين	10	-	10	10	-
النترات	-	50	-	-	10
نتريت معين بالنيتروجين	-	-	1	-	1
النتريت	-	0.1	-	-	1
الفوسفور P	-	5	-	-	-
حدود الاكسجين الحيوي BOD	-	-	-	-	2
الصوديوم Na	200	-150 175	-	-	-

	مواصفات هيئة الصحة العالمية	مواصفات الاتحاد الأوربي	المواصفات الكندية	المواصفات الأمريكية	المواصفات الروسية
الصوديوم Na	200	-150 175	-	-	-
الكوريد CI	250	25	250	250	250
كبريتات So_1	400	25	500	250	500
كبريتيد So_1	-	-	0.05	-	-
فلوريد F	1.5	-1.5 [5](0.7)	1.5	2	1.5
بورون B	-	1	5	-	-
سيانيد CN	0.1	-	0.2	-	0.1
الومنيوم AI	0.2	0.2	-	-	-
ارسنك AS	0.05	0.05	0.05	0.05	-
باريوم Ba	-	0.1	1	1	-
كادميوم Cd	0.005	0.005	0.005	0.01	0.001
كروميوم Cr	0.05	0.005	0.05	0.05	0.1 8(0.5)
كوبلت Co	-	-	-	-	0.1
نحاس Cu	1	1(0.1)	1	1	1
حديد Fe	0.3	0.3	0.3	0.3	0.5

	مواصفات هيئة الصحة العالمية	مواصفات الاتحاد الأوربي	المواصفات الكندية	المواصفات الأمريكية	المواصفات الروسية
رصاص Pb	0.05	0.05	0.05	0.05	0.03
منجنيز Mn	0.1	0.05	0.05	0.05	-
زئبق Hg	0.001	0.001	0.001	0.002	0.0005
نيكل Ni	-	0.05	-	-	-
سلينيوم Se	0.01	0.01	0.01	0.01	-
زنك Zn	5	0.1 – (3)	5	5	1

الملوثات العضوية	مواصفات الصحة العالمية	مواصفات الاتحاد الاروبي	المواصفات الكندية	المواصفات الامريكية	المواصفات الروسية
Oil & Petroleum Products	-	0.01	-	-	0.3
Total Pesticides	-	0.5	0.1	-	-
Individual Pesticides	-	0.1	-	-	-
Aldrin & Dieldrin	0.03	-	0.7	-	-
DDT	1	-	30	-	-
Lindane	3	-	4	0.4	-
Methoxychlor	30	-	100	100	-
Benzene	10	-	-	5	-
Hexachlorobenzene	0.01	-	-	-	-
Pentachlorophenol	10	-	-	-	-
Phenols	-	0.5	2	-	1
Detergents	-	0.2	-	12(0.5)	0.5